National Physical Laboratory

Conference Digest

MINET Conference:
Measurement, sensation and cognition

10 - 12 November 2009

National Physical Laboratory, London, UK

Measuring the Impossible

MINET Conference: Measurement, Sensation and Cognition

10 – 12 November 2009

National Physical Laboratory, UK

Conference Digest

National Physical Laboratory
Hampton Road
Teddington
Middlesex
UK
TW11 0LW

NPL website: http://www.npl.co.uk

MINET website: http://www.measuringimpossible.net

ISBN 978-0-946754-56-4

Foreword

Welcome to the MINET Conference on Measurement, Sensation and Cognition, 2009.

This conference is the fourth in a series of workshops and is organised by the EU Measuring the Impossible Network (MINET) project.

MINET coordinates activities for 'Measuring the Impossible (MtI)' i.e. research in areas of interdisciplinary science aimed at supporting the development of new methods and investigative techniques for the measurement of complex phenomena that are dependent on human perception and/or interpretation. This includes, for example, measurements relating to the perceived attributes of products and services, such as quality or desirability, or the quantification of societal parameters such as security and well-being.

This conference brings together researchers from around the world, working in different disciplines such as science, engineering, psychology, neuroscience and the creative arts, and from a range of different backgrounds, including the manufacturing and design industries, universities, research laboratories and National Measurement Institutes, all of whom have a common interest in research areas that could be considered Measuring the Impossible.

It provides a forum for presentation of the latest research developments in areas such as perception, sensation, cognition, neuropsychology, metrology, data analysis and measurement theory, with 3 keynote invited presentations and a total of 33 contributed oral and poster presentations. The programme also allows the opportunity to discuss and influence the future direction of the Measuring the Impossible research area, through the presentation of the MINET Expert group report and a round-table discussion.

We hope that you enjoy what promises to be a diverse and stimulating technical programme.

Teresa Goodman, NPL

& MINET Workpackage 4 partners

Acknowledgements

The MINET project is funded under the EU 6th Framework programme as a New and Emerging Science and Technology (NEST) Pathfinder project as part of the Measuring the Impossible Theme. EU contract number 043297. This conference is jointly funded by the UK's Department for Business, Innovation and Skills.

Technical Committee

Prof Birgitta Berglund	*Stockholm University, Sweden*
Dr Gregor Geršak	*University of Ljubljana, Slovenia*
Arjan Geven	*CURE - Centre for Usability Research and Engineering, Austria*
Teresa Goodman	*National Physical Laboratory, UK*
Prof Francis McGlone	*University of Liverpool, UK*
Dr Gabriele Quinti & Alessandra Cancedda	*Laboratorio di Scienze della Cittadinanza, Italy*
Dr Niklas Ravaja	*Helsinki School of Economics, Finland*
Dr Gerie van der Heijden	*Biometris, The Netherlands*

Summary Programme

Tuesday 10th November 2009

9:00 – 10:45	Registration & Poster set-up & refreshments	
10:45 – 11:00	Opening Address	
11:00 – 12:00	Keynote Paper: Prof Steve Tipper	1
12:00 – 1:00	Perception and Sensation Session 1	7
1:00 – 2:00	Lunch	
2:00 – 3:30	Perception and Sensation Session 2	19
3:30 – 4:00	Break	
4:00 – 5:30	Perception and Sensation Session 3	31
6:00	Conference Dinner and Tour at Twickenham Stadium	

Wednesday 11th November 2009

8:45 – 9:45	Perception and Sensation Session 4	45
9:45 – 10:30	MINET Expert group report	51
10:30 – 11:00	Break	
11.00 – 12.00	Roundtable discussion	52
12:00 – 1:00	Keynote Paper: Prof Charles Spence	53
1:00 –2:00	Lunch	
2:00 – 3:30	Poster session & refreshments	99
3:30 – 5:30	Analysis and Theories	67

Thursday 12th November 2009

8:45 – 9:45	Keynote Paper: Dr Susan Francis	79
9:45 – 10:45	Cognition & Neuropsychology Session 1	83
10:45 – 11:15	Break	
11:15 – 12:45	Cognition & Neuropsychology Session 2	89
12:45 – 12:55	Closing Address	
12:55 – 1:00	Closing remarks	

Conference officially closed

2:00 – 3:30 Post-conference lab tours (optional)

Detailed Programme

MINET Conference: Measurement, Sensation and Cognition

10 – 12 November 2009

TUESDAY 10TH NOVEMBER 2009

9:00 – 10:45 Registration & Poster set-up & refreshments

10:45 – 11:00 Opening Address
Dr Julie Taylor, National Physical Laboratory, UK

Perception and Sensation

11:00 – 12:00 **Keynote Paper**: 1
Motor activation via action observation: Effects on object and person attributes
Steven P. Tipper
School of Psychology, Bangor University, UK

Perception and Sensation Session 1

Chair: Prof Birgitta Berglund

12:00 - 12:30 Emoacoustics: Using auditory-induced emotion to improve sound design 7
Daniel Västfjäll. Presented by Ana Tajadura
Division of Applied Acoustics, Chalmers university of Technology, Sweden

12:30 - 1:00 Human-mimicking environmental sound measurement 12
Dick Botteldooren, Damiano Oldoni, Bert De Coensel
Acoustics Group, Department of Information Technology, Ghent University, Belgium

1:00 – 2:00 Lunch

Perception and Sensation Session 2

Chair: Dr Gerie van der Heijden

2:00 – 2:30 Synthesizing Visual Textures for Predefined Aesthetic Properties 19
Stefan Thumfart, Christian Eitzinger
Profactor GmbH, Im Stadtgut A2, 4407 Steyr-Gleink, AUSTRIA

2:30 – 3:00 Perceived randomness of surface textures 23
K. Emrith[1], P. R. Green[2], M. J. Chantler[1]

[1]School of Mathematical and Computer Sciences, Heriot-Watt University, Scotland, U.K.
[2]School of Life Sciences, Heriot-Watt University, Scotland, U.K.

3:00 – 3:30 The Rasch model as a measurement model in affective engineering 24
Brian Henson
School of Mechanical Engineering, University of Leeds

3:30 – 4:00 Break

Perception and Sensation Session 3

Chair: Ruth Montgomery

4:00 – 4:30 Measuring Colour Constancy and Colour Appearance: an Experiment 31
Alessandro Rizzi[a], Carinna Parraman[b], John J. McCann[c]
[a]Università degli Studi di Milano, Italy
[b]Centre for Fine Print Research, University of the West of England, Bristol, BS3 2JT
[c]McCann Imaging, Belmont, MA 02478 USA

4:30 – 5:00 How many surfaces in natural scenes can be identified by their colour? 34
David H. Foster,[1,] Iván Marín-Franch,[1,**] Kinjiro Amano,[1] and Sérgio M. C. Nascimento[2]*
[1]School of Electrical and Electronic Engineering, University of Manchester, Manchester M60 1QD, UK
[2]Department of Physics, Gualtar Campus, University of Minho, 4710-057 Braga, Portugal
***Current address: Department of Biomedical Sciences and Human Oncology, University of Turin, Turin 10126, Italy*

5:00 – 5:30 Measuring Effects of Wall Colours on Perceived Room Spaciousness 38
David Elliott, Fiona McLachlan
Akzo Nobel Decorative Coatings, Slough, UK

6:00 Departure from NPL for Conference Dinner and Tour at Twickenham Stadium

WEDNESDAY 11TH NOVEMBER 2009

Perception and Sensation Session 4

Chair: Dr Gregor Geršak

8:45 – 9:15 Time-order effects in timed brightness and size discrimination 45

of paired visual stimuli
Geoffrey R. Patching, Mats P. Englund and Åke Hellström
Department of Psychology, Stockholm University, Sweden

9:15 – 9:45 MEMORY: Measuring and modelling perceptual space-time 46
G. M. Cicchini[1] and M. C. Morrone[1]
[1] Dipartimento di Scienze Fisiologiche, Università degli Studi di Pisa, Pisa, Italy

Measuring the Impossible

Chair: Dr Kamal Hossain

9:45 – 10:30 MINET Expert group report 51

10:30 – 11:00 Break

11.00 – 12.00 Roundtable discussion 52

12:00 – 1:00 **Keynote Paper** 53
Measuring the impossible
Prof Charles Spence
Department of Experimental Psychology, Somerville College, Oxford University, UK

1:00 –2:00 Lunch

2:00 – 3:30 Poster session & refreshments
Please see below for list of posters

Analysis and Theories

Chair: Adj Prof Leslie Pendrill

3:30 – 4:00 MINET projects in the context of general measurement and instrumentation science 67
Ludwik Finkelstein
Measurement and Instrumentation Centre, City University London, UK

4:00 – 4:30 Emerging Paradox and The Role of Context in the Exploration of Human Ability and Performance 70
M.Layne Kalbfleisch
KIDLAB, George Mason University, Fairfax, VA 22030

4:30 – 5:00 On combining different psychophysical scaling methods 72
Agnieszka Bialek[1], Krista Overvliet[2,3], Gerie van der Heijden[4]
[1]National Physical Laboratory, Teddington, UK
[2]Departament de Psicología Bàsica, Universitat de Barcelona, Barcelona, Spain

[3]*Departament de Tecnologies de la Informació i les Comunicacions, Universitat Pompeu Fabra, Barcelona, Spain*
[4]*Biometris, Wageningen University and Research Centre, The Netherlands*

5:00 – 5:30	Ratio scales revisited *Giovanni B. Rossi, Francesco Crenna* *DIMEC - Università degli Studi di Genova, Genova, Italy*	74

Free evening

THURSDAY 12TH NOVEMBER 2009

Cognition & Neuropsychology

8:45 – 9:45	**Keynote Paper** Challenges and Opportunities of Ultra-High Field MRI *Susan Francis* *Sir Peter Mansfield Magnetic Resonance Centre, Nottingham University, UK*	79

Cognition & Neuropsychology Session 1

Chair: Dr Gabriele Quinti

9:45 – 10:15	Psychophysical and neuroimaging investigations of human touch: discriminative and affective properties *Francis McGlone* *Sensation, Perception & Behaviour Group, Unilever R&D, U.K; Sir Peter Mansfield Magnetic Resonance Centre, University of Nottingham, UK*	83
10:15 – 10:45	The concept of mapping phenomenal space in somatosensation: Multi-dimensional scaling of pain perception [1]*Dieter Kleinböhl, Jörg Trojan, Rupert Hölzl* [1]*University of Mannheim, Otto-Selz-Institute for Applied Psychology, Laboratory for Clinical Psychophysiology; D-68131 Mannheim*	84
10:45 – 11:15	Break	

Cognition & Neuropsychology Session 2

Chair: Prof Francis McGlone

11:15 – 11:45	‘Mind-reading’ approaches: from cognitive neuroscience to clinical applications *Janaina Mourao-Miranda[1,2] and Andre Marquand[2]* *1 - Department of Computer Science, Centre for Computational Statistics and Machine Learning, University College London, UK*	89

2 - Department of Clinical Neuroscience, Institute of Psychiatry, King's College London, UK

11:45 – 12:15 Measuring truth with psychological and neuroscientific methods 92
Hans J. Markowitsch and Angelica Staniloiu
Physiological Psychology, University of Bielefeld, Bielefeld, Germany

12:15 – 12:45 Visual processing in natural viewing: Understanding eye movements and brain activity using a fixation-based event-related approach 95
J.B.C. Marsman[1,2], J.R. Helmert[3], R.Renken[1,2], F.W. Cornelissen[1,2], S. Pannasch[3] & B.M. Velichkovsky[3]
1: Laboratory of Experimental Ophthalmology, University Medical Center Groningen, Groningen, The Netherlands
2: BCN NeuroImaging Center, University of Groningen, Groningen, The Netherlands
3: Institute of Psychology III, Technische Universitaet Dresden, 01062, Dresden, Germany

12:45 – 1:00 Closing Address
Prof Birgitta Berglund, Stockholm University, Sweden

Conference officially closed

Post-conference lab tours (optional)

2:00 – 3:30 Lab tours

Poster session

1. Personalised blood pressure monitor 99
Gregor Geršak and Janko Drnovšek
University of Ljubljana, Faculty of Electrical Engineering, Ljubljana, Slovenia

2. Objective Characterisation of Food Textural Properties in Relation to Sensory Perception 103
Jianshe Chen,[1] Malcolm Povey,[1] Andrea Utley,[2] and Yadira Gonzalez[1]*
[1] School of Food Science and Nutrition, University of Leeds, Leeds LS2 9JT
[2] Centre for Sport and Exercise Sciences, University of Leeds, Leeds LS2 9JTDr

3. Perceiving colour in natural scenes: constancy of colour categories 107
Kinjiro Amano[#], David H. Foster
School of Electrical and Electronic Engineering, University of Manchester, Manchester, UK

4. Measurement with Persons: Concepts & Techniques as studied in MINET Repository and Think Tanks 111
L R Pendrill
SP Technical Research Institute of Sweden, Measurement Technology, Box 857, SE-50115 Borås (SE)
B Berglund (MINET coordinator)[1], A Alfonsi[2], A Cancedda[2], F Crenna[3], J Drnovsek[4], R Emardson[5], G Gersak[4], G van der Heijden[6], A Höglund[1], K Kallinen[7], N Ravaja[7] and G. B. Rossi[3]
[1]Stockholm University, Department of Psychology, SE-106 91 STOCKHOLM (SE)
[2]Laboratory of Citizenship Science (LSC), Via Monte Zebio, 32 - 00195 ROME (IT)
[3]DIMEC, Dept. of Mechanics and Machine Design,Via all'Opera Pia 15A, University of Genoa, I - 16145 GENOVA, (IT)
[4]University of Ljubljana, Faculty of Electrical Engineering, Trzaska 25, 1000 LJUBLJANA (SLO)
[5]SP Technical Research Institute of Sweden, Measurement Technology, Box 857, SE-50115 BORÅS (SE)
[6]Wageningen UR, Biometris, PO Box 100, 6700AC WAGENINGEN (NL)
[7]Helsinki School of Economics, Centre for Knowledge and Innovation Research, Box 1210, FIN-00101 HELSINKI (FIN)

5. Spy-See - Advanced vision system for phenotyping in greenhouses 115
G. Polder[1], G.W.A.M. Van Der Heijden[1], C.A. Glasbey[2], Y. Song[2] and J.A. Dieleman[3]
[1]Wageningen UR, Biometris, P.O. Box 100, 6700 AC, Wageningen, Netherlands, [2]Biomathematics & Statistics Scotland, JCMB, The Kings buildings, Edinburgh EH9 3JZ, Scotland, United Kingdom, [3]Wageningen UR, Plant Research International, P.O. Box 16, 6700 AA, Wageningen, Netherlands.

6. Designing Environments for the Elderly: Measuring and Tracing the Shifts in Emotional Responses 118
Alessio Corso, Hilary Dalke, Laura Stott, Uta Krieger*
Kingston University, Design Research Centre, United Kingdom

7. An explorative study of materials' perceptive and associative properties 120
Caroline Cederström, Siv Lindberg, Mikael Lindström
Innventia

8. Investigating the Acoustic Properties of Materials with Tuning Forks 124
Wongsriruksa, S[1]., Laughlin, Z. [1], Naumann, F. [1], Conreen, M. [2], and Miodownik, M. A. [1]
[1] Materials Research Group, Engineering Division, King's College London.
[2] Design Department, Goldsmiths College, London.

9. The Taste of Materials: Spoons 127
Laughlin, Z. [1], Conreen, M. [2], Witchel, H. [3] and Miodownik, M. A. [1]
[1] Materials Research Group, Engineering Division, King's College London.
[2] Design Department, Goldsmiths, University of London.
[3] Brighton and Sussex Medical School, University of Sussex.

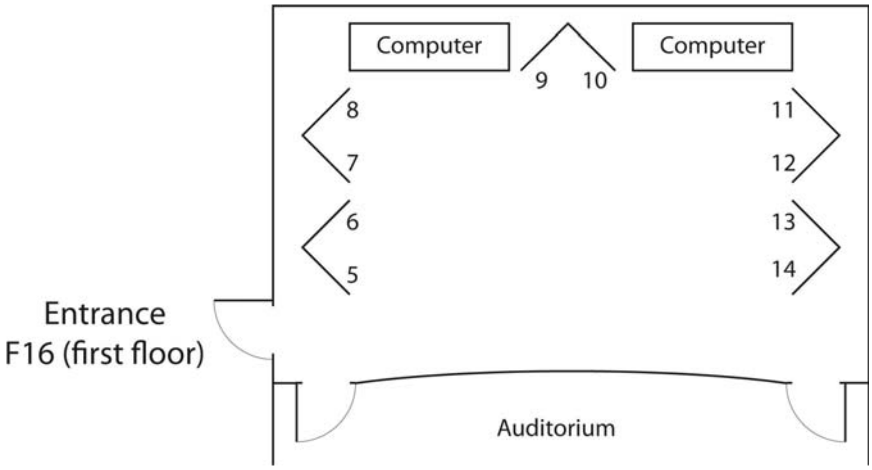
10. Interdisiplinarity and sound environment research 129
Frans Mossberg
Sound Environment Centre, musicology, Lund University, Sweden

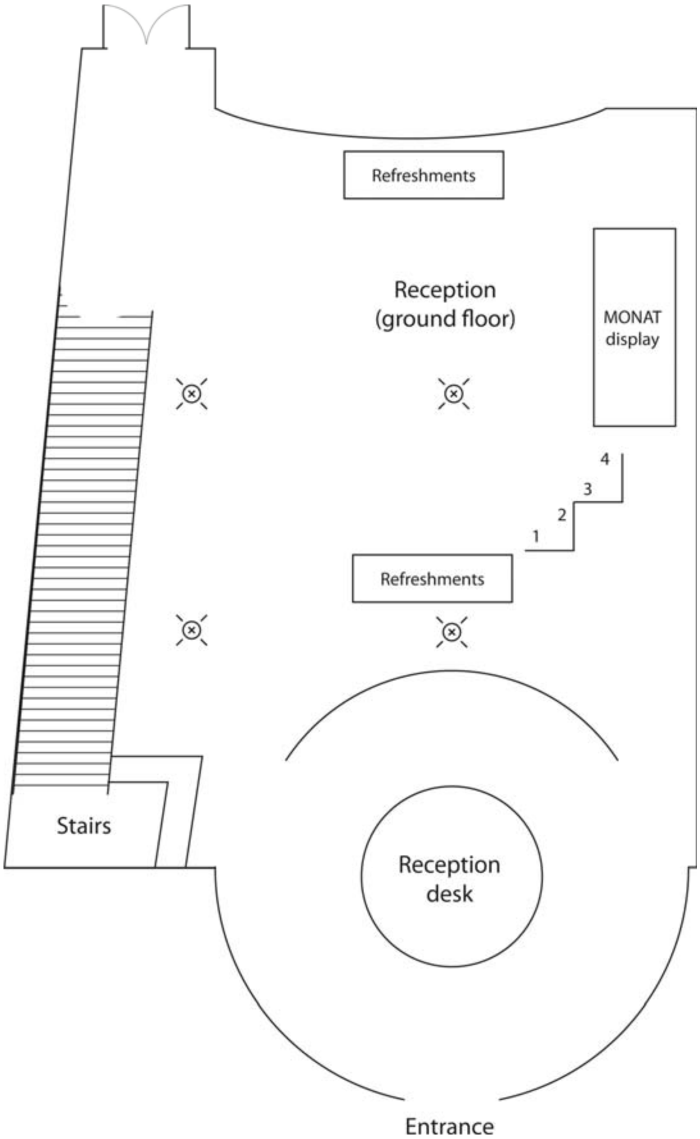
11. Measurement for a more visible world: colour contrast and visual impairment 134
Hilary Dalke, Gareth Conduit†, Bryce Conduit[+], Alessio Corso**
** Design Research Centre, Kingston University*
† Theory of Condensed Matter Group, Cavendish Laboratory, Cambridge
[+] Department of Materials Science and Metallurgy, University of Cambridge, Cambridge

12. Subjective and objective measurements in the context of sonic interactions 139
Guillaume Lemaitre, Patrick Susini, Nicolas Misdariis, Olivier Houix
IRCAM, 1 place Stravinsky, 75004 Paris, France

13. Measurement of physiological parameters using ultra-high impedance electric potential sensors 144
H. Prance, P. Watson, S. T. Beardsmore-Rust, C. J. Harland, R. J. Prance*
Centre for Physical Electronics and Quantum Technology, School of Engineering and Design, University of Sussex, Falmer, Brighton, BN1 9QT, U.K.

14. How to disentangle between luminance and cognitive load on pupil dilation measurement 148
Chiara Aghemo, Thierry Baccino**, Lauretta Chiaraviglio*, Valerio Lo Verso*, Laura Rossi **
** Politecnico di Torino, Department of Energetics, TEBE Research Group, Torino, Italy.*
*** LUTIN-UMS-CNRS 2809, Cité des sciences et de l'industrie de la Villette, Paris, France*


Computer
Computer
9
10
8
7
6
5
11
12
13
14
Entrance
F16 (first floor)
Auditorium


Refreshments
Reception
(ground floor)
MONAT
display
4
3
2
1
Refreshments
Stairs
Reception
desk
Entrance

Keynote Paper

Motor activation via action observation: Effects on object and person attributes

Steven P. Tipper

School of Psychology, Bangor University, UK

There is an increasing appreciation for the intimate link between vision and action. As Gibson (1979) noted, sensory systems such as vision specifically evolved to serve action, to allow an animal to interact with its environment. Substantial evidence that this conversion from vision into action is automatic, taking place even when a person has no intentions to act on a viewed object, has accrued over recent years. For example, Tucker and Ellis (1998) showed that merely viewing an object that affords an action appears to activate that action. Thus, seeing a coffee cup activates the motor responses to grasp the cup, even though at no time is it necessary to actually grasp the cup. Such results support the notion that we represent our world primarily as opportunities for action.

This automatic conversion from vision to action also takes place, not just when looking at inanimate objects that can be acted upon, but also when viewing other people's actions. The discovery of mirror neurons (di Pellegrino, Fadiga, Fogassi, Gallese & Rizzolatti, 1992) promoted this notion. Cells in ventral premotor cortex area F5 respond when a monkey grasps an object in a particular manner. Importantly, however, the same cell will respond when the monkey sees another individual produce the same action. Thus the same neural system encodes the actions of another individual as well as the animal's own actions. These mirror processes have now been detected in humans, and it has been proposed that these mapping processes from other to self provide one means of understanding other people, by representing their actions as actions we could perform ourselves.

We have recently shown that the conversion of visual inputs into action-based representations is even more widespread than first thought. For example, when viewing the faces of particular individuals, actions of body parts such as the hand or foot can be detected. That viewing a face can activate a foot response more than a hand response, for example, would seem to be counter-intuitive. However, this reflects deeper semantic analysis when identifying the person's face. For example, if the individual happened to be a famous soccer player such as Wayne Rooney, then access to his profession appears to activate motor responses such as the skilled movements of the feet associated with that profession, and this influences the participant's own foot responses (see Bach & Tipper, 2006).

A further important feature of the relationship between vision and action is that it is bi-directional. Not only is vision automatically converted in to action, but activation of action states can feedback and influence the perception of visual stimuli. I discuss a number of examples of this latter point. First, when we observe another individual make a sudden gaze shift to the left and right, our own attention system appears to simulate this process and we shift attention to the same location. This joint attention state, where the attention of two individuals is directed to the same object, facilitates object processing, but it also appears to alter the emotional response to the object. That is, after viewing other people orient their gaze to some objects, participants start to report increased liking of those objects, as if internalizing the preferences of the viewed person.

Second, we have extended such findings to the observation of reaching actions. Participants observe other people reach out and pick up an object, and then place this object in a new location. We manipulated the fluency of this action. In the non-fluent condition the action is complex and more difficult to execute. That is, the object has to be moved carefully around a fragile obstacle (a thin glass vase full of water). In contrast, in the fluent action condition, obstacle avoidance is unnecessary. Even though participants make no actions themselves while merely observing these actions, they report greater liking of objects moved in the more fluent conditions, as if they had acted on the object. Hence simulation of actions can also alter emotions such as liking (See Hayes Paul, Beuger, & Tipper, 2008).

Third, in a final set of studies we examined how another person would be represented, depending on the simulation processes their actions evoked in an observer. In one study faces were seen to look towards or away from objects. Unbeknown to the participant, the faces were consistent in their looking behaviour. For example, one individual might always look towards target objects (predictive-valid), while a different individual might always look away (predictive-invalid). Although participants were completely unaware of the face identity-gaze cueing contingency, nevertheless we found effects on trust. That is, when asked to choose between a face that always looked towards targets and one that always looked away, people reported more trust of the former (Bayliss & Tipper, 2006; Bayliss, Griffiths & Tipper, 2008).

A final study extended this idea to show that activating motor states when observing a person can feedback and influence how that person is perceived. Participants identified two individuals, George with a foot response and John with a finger response, for example. These people were shown either typing on a key-board or kicking a soccer ball. Stimulus response compatibility effects were observed, where observing someone kick a ball activated similar foot responses in the observer and facilitated the foot as compared to the finger response. However the more important results was that after the experiment, when rating George and John as sporty or academic individuals, the visuomotor fluency activated by their previous action fed back and influenced how they were perceived. Thus if George had been identified with a foot response, response times were faster and errors lower when he was viewed kicking a ball as compared to typing. The fluency of the participant's responses while viewing George kicking a ball was then misattributed to George, and he was considered to be more sporty, even thought there was no objective information in the visual array to support this assessment (see Bach & Tipper, 2007; Tipper & Bach, 2008).

In sum, passively viewing visual objects or people can activate action-based representations. Seeing a person shifting their gaze automatically orients our own gaze and attention to the same object, just as seeing more global actions such as kicking a ball, activates congruent motor responses of the foot. The automatic activation of these motor states can in turn feedback and influence our interpretation of the visual world. Hence, objects might be liked a little more, and people trusted more, due to activation of motor states. Therefore body/action systems are activated to represent current states of the world, as when viewing objects and people; and subsequently these body-centred representations are used to interpret future states of the world in later assessments of those same objects and people (see Tipper, in press for review).

References:

Bach, P. & Tipper, S.P. (2006). Bend it like Beckham: Embodying the motor skills of famous athletes. *Quarterly Journal of Experimental Psychology*, 59, 2033-2039.

Bach, P. & Tipper, S.P. (2007). Implicit action encoding influences personal-trait judgments. *Cognition*, 102, 151-178.

Bayliss, A.P., Griffiths, D. & Tipper, S.P. (2009). Predictive gaze cues affect face evaluation: The effects of facial emotion. *The European Journal of Cognitive Psychology*, 21, 1072-1084.

Bayliss, A.P. & Tipper, S.P. (2006). Predictive gaze cues and personality judgements: Should eye trust you. *Psychological Science*, 17, 514-520.

Di Pellegrino, G., Fadiga, L., Fogassi L., Gallese, V. & Rizzolatti, G. (1992). Understanding motor events: A neurophysiological study. *Experimental Brain Research,* 91, 176-180.

Hayes, A.E., Paul, M.A., Beuger, B. & Tipper, S.P. (2008). Self produced and observed actions influence emotion: The roles of action fluency and eye gaze. *Psychological Research*, 72, 461-472.

Tipper, S.P. (in press). From observation to action simulation: The role of attention, eye-gaze, emotion and body-state. *The Quarterly Journal of Experimental Psychology*,

Tipper, S.P. & Bach, P. (2008). Your own actions influence how you perceive other people: a misattribution of action appraisals. *Journal of Experimental Social Psychology,* 44, 1082-1090.

Tucker, M. & Ellis, R. (1998). On the relation between seen objects and components of potential actions. Journal of Experimental Psychology: Human Perception & Performance, 24, 830-846.

Perception and Sensation Session 1

Tuesday 10th November

12:00 – 1:00 pm

Chair: Prof Birgitta Berglund

Emoacoustics: Using auditory-induced emotion to improve sound design

Daniel Västjäll

Division of Applied Acoustics, Chalmers university of Technology, Sweden

Emotions are central in everyday life and the science of emotion has recently flourished. It is now well established that emotions or affective processes are an integral part of human judgment and decision making (Peters et al., 2006) and perception (Niedenthal, 2007). Negative emotions are considered a determinant of worsened health and, recent research has shown that positive emotions may increase resilience and lead to better health (Fredrickson, 2001; Hanser, in press). In addition, it is well established that emotional processes influence, and is influenced by, cognitive and perceptual processes.

Some branches of perceptual psychology have recognized the important role of emotions and focused on how visual stimulus features (Silva, 2008) and musical features in interaction with psychological mechanisms (Juslin & Västfjäll, 2008) can elicit emotional responses. However little systematic research has so far focused on how sound auditory objects or auditory events elicit emotions. Psychoacoustics traditionally has dealt with how "sensations are linked to physical properties". While sensations typically are non-emotional (i.e. the psychological sensations of the loudness of a sound), many psychoacoustical investigations have investigated how physical properties lead to emotional responses (i.e. the increase of annoyance with increased loudness or noisiness; Berglund et al., 1975). Thus, in some sense, emotional responses to physical stimulus features has for long been studied (see Wundt). We argue, that the bulk of emotional responses to sounds cannot be captured by physical properties alone (typically studies of noise annoyance finds that about 30% of the variance in annoyance ratings can be accounted for by physical attributes), and that current research in psychoacoustics lack a systematic approach that describe the underlying psychological mechanisms creating an emotional response. With evidence mounting that emotion is integral in many perceptual processes and perceptual judgments, we argue that it is time to bring emotion into psychoacoustics. The approach I present here focus on how sound can elicit emotion and is therefore qualitatively different from traditional psychoacoustics. We therefore term this approach emotional acoustics, or emoacoustics.

The aim of this overview is to summarize some of the existing research on emotional responses to sounds. We further aim to provide a theoretical framework and description of some of the underlying mechanisms that may be activated during the perception-emotion process. I will demonstrate the usefulness of emoacoustics for sound design and product sound quality.

Why emotion?

The basic question addressed here is: how does sound elicit emotion? This is a non-trivial question that will require integrative analyses of areas such as perception, emotion, neuroscience, health and associated areas. It may however be asked why considering emotion is central in research in auditory perception?

First, as argued earlier, emotion is central in our everyday life. Emotions informs us about our relationship to the surrounding environments (Schwarz & Clore, 2007). From an evolutionary perspective affect can be seen as the human alarm system. Positive affect signals that everything is safe and no specific action is needed to be undertaken to survive, while negative affect signals a potential threat and need to take action. Affect thus have strong consequences for behavior and information processing. It may be argued that affect has four separate roles First, as described above, affect can act as *information*. Second, it can act as a *spotlight* focusing us on different information depending on the extent of our affect. Third, affect can *motivate* us to take action or do extra work. Finally, affect may serve as a *common currency allowing us to compare apples and oranges* (Cabanac, 1992).

In our everyday life, sound often elicits emotional reactions in the listener. People can be startled by the sudden sound of a door slamming or a thunder in a storm, annoyed by the noise of cars in the street, pleased by the sound of a water stream in the forest, tired after a full day of work in a noisy environment, etc. Thus, understanding the role of sound in evoking human affective responses might improve our quality of life by helping to design objects, spaces and media applications which are *emotionally optimized*. Understanding emotional responses to sound may also help preventing negative effects of sounds, including health effects.

However, myths pervade the study of emotional responses to sounds. One popular myth is that there is a universal sound that will be liked or reacted to in the same way by everyone. We argue that emotional optimization of sound cannot be achieved from this perspective. Emotional responses will depend on the interaction of the stimulus (form characteristics), the listener and the situation. Thus, one sound may elicit a specific reaction in one listener/situation, but an entirely different in another situation/listener. This may seem like a pessimistic view, where it may appear impossible to predict when a sound will elicit emotional responses. We will however show that it is possible to predict emotional responses to sound, by considering the stimulus and psychological features at the same time.

So far, research in this area has been trying to connect physical sound properties and basic emotional responses. However, it seems more meaningful to divide ongoing research on affective reactions to sounds into four main categories; 1) Physical determinants, 2) psychological determinants, 3) spatial determinants and 4) cross-modal determinants (Västfjäll, Tajadura, Väljamäe, Juslin, in preparation : title Non-vocal, non-musical determinants of auditory induced emotions.

Psychological determinants concerns other variables related to subjective interpretation and meaning that should be considered because different sources evoke different subjective evaluations (Jancke, Vogt, Musial, Lutz, & Kalveram, 1996) (e.g. dog barking vs. rock music). Spatial determinants deals with the role of the auditory space in creating an emotional response (for instance, the barking dog will have different emotional effects if the spatial cues would suggest that the space is small vs. big). Finally, cross-modal effects concern the relation between different modalities in producing an affective reaction (De Gelder & Bertelson, 2003). While much research still is needed to fully understand the different determinants of affective reactions to different categories of sounds, we highlight these four categories in the present review.

The emoacoustic framework

In a recent review of how music elicits emotion (Juslin & Västfjäll, 2008) we outlined seven psychological mechanisms through which music might be expected to evoke emotions:

(1) *brain stem responses,* related to 'pre-wired' attentional responses to simple acoustic
characteristics of the music (e.g., loudness, speed),
(2) *evaluative conditioning*, related to the regular pairing of a music stimulus and other
positive or negative stimuli,
(3) *emotional contagion*, related to an internal 'mimicry' of the perceived emotional expression of the music,
(4) *visual imagery*, related to visual images of an emotional nature conjured up by the listener while listening to the music,
(5) *episodic memory*, related to specific memories from the listener's past evoked by the
music,
(6) *music expectancy*, related to the gradual unfolding of the musical structure and how
this may provoke emotions (e.g., surprise) the listener, and
(7) *cognitive appraisal*, related to an evaluation of the music on a number of dimensions
in relation to current goals or plans of the individual.

While some of these mechanisms are music-specific it appears that the framework in a slightly modified manner can be used for non-musical, non-vocal sounds as well. The musical framework was recently reduced to cover two main mechanism in which through sound may elicit emotion; 1) either a sound will elicit immediate responses (arousal potential; Berlyne, 1971; Vitz, 1973) or sound properties will be matched to previously stored representations or associations (familiarity/significance check; Näätänen & Winkler, 1999; Näätänen et al., 1989). In both cases the sound will elicit both a reaction and an evaluation of the possible danger or threat of the situation (as signaled by the sounds; Belin & Zatorre, 2000). This framework thus maintain the first music mechanism (brain stem response) and unify the remaining mechanisms into one umbrella description (Västfjäll et al., 2006; 2007).

The first mechanism, arousal potential, is a preattentive warning system that has evolved to compute a quick assessment of the potential threat of the situation (Jacobsen et al., 2003; Ledoux, 2000). This system must be extremely fast and elicit immediate and correct responses to ensure survival. Evidence points to that human are hardwired to react to certain extreme acoustical characteristics (loud, sharp noises; Bradley & Lang, 2000). Thus when a sound exceeds a certain arousal threshold it will activate fight and flight tendencies (Giard et al., 1995; Lang, 1995). In support of this function, some recent research has shown that loud noise bursts are rapidly transferred from the primary auditory cortex to the amygdala, a brain region responsible for preparing the body for approach and avoidance behavior (Ledoux, 2000). This route is likely rather homogenous across individuals (Owren, Rendall & Beharowski, 2003).

If the sound does not carry an arousal potential that exceeds the threshold, it will be processed by other parts of the brain (Belin & Zatorre, 2000; Peretz & Zatorre, 2005). First, the secondary auditory cortex will process the sound followed by associative and motor cortex areas (Edeline & Weinberger, 1992). Here the incoming sound will be compared to sound representations stored in long-term memory (Saarinen et al., 1992). If the sound has been encountered before (or resembles a sound that has been encountered before) it will elicit one of two possible reactions (Jääskelinen et al, 2004): 1) If it is an unfamiliar sound, it will immediately signal the same alarm system as a sound with high arousal potential. The same holds true if the sound matches a sound representation that is associated with a previous negative experience (Damasio, 1994; Damasio et al., 2000). If the sound matches a previously stored representation it will be further evaluated on basis of it significance for survival (Belin & Zatorre, 2000; Tood, 2001). If our previous experience has coded the sound as something potentially threatening or coexisting with something else that may be a threat, the system will call for an action. If, on the other hand, the sound is evaluated as non-harmful no action will be required. This route will vary across individuals and depend on their previous exposure as well as culture.

This framework also underlines the implicit *embodied* and *multimodal* nature of emotional sound perception. When interacting with our surrounding environment, our survival directly depends on the abilities to keep a constant margin of safety around our body. In this interaction with the environment, our body plays a major role acting as a reference frame (Damasio, 1994) and forming the basis for information processing, including cognitive, perceptual, emotional and action response processing (see embodiment theories, Niedenthal et al., 2005). The margin of safety surrounding our body can be achieved thanks to our perceptual system, which continuously monitors the nearby space in order to alert us of any significant events requiring an action from our side. Negative affect signals a potential threat and need to take action. Emotions arise in response to significant events and evoke an automatic, frequently prior to awareness, response that modulates the subsequent attentional, perceptual and behavioral processes (Damasio, 1994). Hence, they serve then to establish our position vis-à-vis our environment (Clore & Huntsinger, 2007). Moreover, the auditory sense is only one source of information. Other senses such as vision, taste, olfaction and tactile senses work in concert with the auditory modality to determine the overall perception and reaction. Thus, emotional responses to sounds are *multimodally determined*.

The emoacoustic framework has a number of implications for design and evaluation of sound. To illustrate, let us consider the case of warning and information sounds in a working environment. First, the framework postulates that warning sounds should have a certain degree of arousal potential so that it evokes an immediate correct response. Second, it suggests that both information and warning sounds would benefit from have sound elements that are familiar (such as auditory icons that rely on naturally occurring sounds to convey information; Gaver, 1993). Third, the proposed framework suggest that emotional reactions to sounds is a common currency with which the urgency, behavioral significance and need action will be evaluated against (Damasio et al., 2000). Examples of data collected using self-reports, behavioral tasks, and psychophysiological measures will be given.

Main references

Juslin, P. N., & Västfjäll, D. (2008). Emotional responses to music: The need to consider underlying mechanisms. *Behavioral and Brain Sciences, 31,* 559-575.

Larsson, P & Västfjäll, D. (in press). Emotion-based design of auditory vehicle information

signals. *International Journal of Human-Computer Interaction.*

Västfjäll, D. (2003). *Affect as a component of perceived sound and vibration quality in aircraft*. Dissertation**,** Report 03-03, Chalmers University of Technology, Sweden.

Västfjäll. D. (in press). Emotion and sound design. In F. Mossberg (Ed.), *Sound design.*

Lund, Sweden: Lyssnande Lund - Ljudcentrum.

Västfjäll, D., & Kleiner, M. (2002). *Emotion and product sound design. In Proceedings of*

Journeés Design Sonore, Paris, 20-21 March 2002.

Human-mimicking environmental sound measurement

Dick Botteldooren, Damiano Oldoni, Bert De Coensel

Acoustics Group, Department of Information Technology, Ghent University, Belgium

Introduction

Classical environmental noise measurements determine the acoustic intensity at the point of observation. Attempts to measure more accurately what persons perceive have mainly focussed on using indicators such as loudness, sharpness, roughness, etc. that were proven to correlate well to perception of sound that test persons attentively listened to in lab environments. The listening context is however very different in everyday life. Therefore a different approach is proposed namely to mimic human processing of environmental sound in computational models and eventually in measurement equipment. The amount of scientific knowledge on the different stages of (environmental) sound perception is huge and continuously growing. However, while trying to implement this knowledge in computational models one has to face the limitations of computers and measurement equipment. The use of supercomputers in environmental noise measurement is not practical since it would scale poorly with the number of measurement microphones. This paper reports on continuous efforts to construct just-accurate-enough human mimicking processing, rigidly grounded in psychological and biological knowledge. In selecting models for every step of this complex process, biological plausible solutions are opted for, which may or may not be the most efficient on current computers, but are surely most future proof.

Computational modelling framework

In previous work[1-3], modelled environmental noise was used as a starting point to analyse how the combined exposure to unwanted sounds such as traffic noise and more pleasant natural sounds (birds, water, etc.) affected soundscape perception. A very simplified notice-event model already shows that including temporal fluctuation at a time scale of seconds can explain some of the observations related to annoyance perception of different sound sources[4]. Thus, time will play an important role. A second crucial factor in environmental noise perception is attention. Both inward and outward oriented attention have to be included in the model[1-2]. Outward oriented attention depends on activity and intentions of the modelled observer. The only possibility to include some of the effects of this form of attention consists in modelling a large number of virtual observers at any given location and look for the average effects. Inward oriented attention focussing depends on features of the environmental sound that attract attention, so called saliency[3]. In modelling the effect of attention on environmental sound perception, the interplay between activation and inhibition-of-return proved essential for obtaining a stable and robust model.

When using modelled or artificially mixed sounds, the problem of auditory stream segregation is avoided. Here we will mainly focus on the additions to the model that are proposed for object formation and stream segregation. The proposed model starts from basic features, extracted from a time-frequency representation of the sound. Currently, specific (Zwicker) loudness *vs.* time is considered as a time-frequency representation, because it can be calculated relatively fast from standard 1/3-octave band levels. The extracted features mimic the information processing stages in the central auditory system. In particular, the human auditory system is, next to absolute intensity, also sensitive to spectro-temporal irregularities (i.e. contrast on the frequency scale, and changes in time). Intensity, spectral and temporal features are calculated by convolving the specific loudness *vs.* time with (difference-of-)gaussian filters with varying width, and thus encode the intensity, spectral and temporal gradient. These feature extraction mechanisms are largely inspired by those used in the calculation of more complex auditory saliency maps[5,6].

The current model extracts 16 intensity, spectral and temporal feature vectors per second, with each vector consisting of 48 values (2 per critical band). This multitude of features has to be organized and lowered in dimension, mainly based on co-occurrence. Features that always occur together most likely belong to a single sound object. Groups of features that are present at the same time, but not usually co-occur should be separated into several streams. Once these streams are formed, one can attend more to one of them. This additional attention may eventually lead to further segregation.

The determination of co-occurrence of features is modeled by constructing a self-organizing map[7] (SOM) based on long periods of observations at a location under study. The resulting two-dimensional maps might differ depending on the region where the training data was gathered. Once training has been achieved, every new observation projects onto a particular area of the map. If the observation contains one set of features that regularly occur together, the projection will be well focussed on a particular region of the map. This corresponds to one *sound* being heard. If however the observation contains various sets of features that do not regularly co-occur several areas of the map get activated. An example is shown in Figure 1, left.

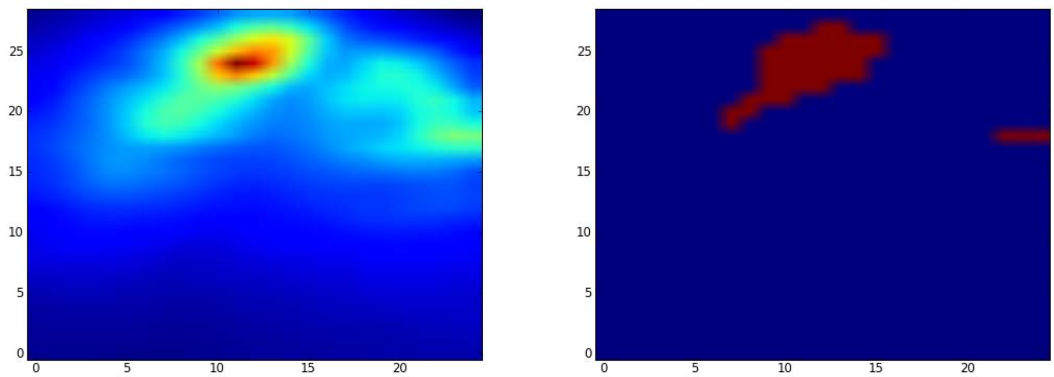


Figure 1. Left: Projection of a new feature set on the map after training. Blue zones correspond to great distance between the new event feature content and the particular nodes of the map, whereas red zones indicate a small distance (high similarity). One big area is visible in the upper center and one smaller is visible on the upper right hand. Right: Binarization of the similarity map on the left. This map corresponds to the external stimulation provided to the LEGION.

To identify whether a sound fragment contains one, two or more streams of sound, another processing step is needed. A Locally Excitatory Globally Inhibitory Oscillator Network[8] (LEGION) is used for segregating areas in a two-dimensional map. The previous map, after being binarized through the use of a threshold, provides the external stimulation to a LEGION network (See Figure 1, right). A threshold permits to mark the interested regions, possibly modulated by attention mechanisms. , The oscillatory correlation at the base of LEGION mimics the biological activity of the brain: coherently perceived objects are linked together by various feature detecting neurons via their specific temporal correlation[9]. Because this type of network is mostly used with static images, it had to be adapted to work with the temporally changing exited regions in the SOM. An example of the model output is shown in Figure 2.

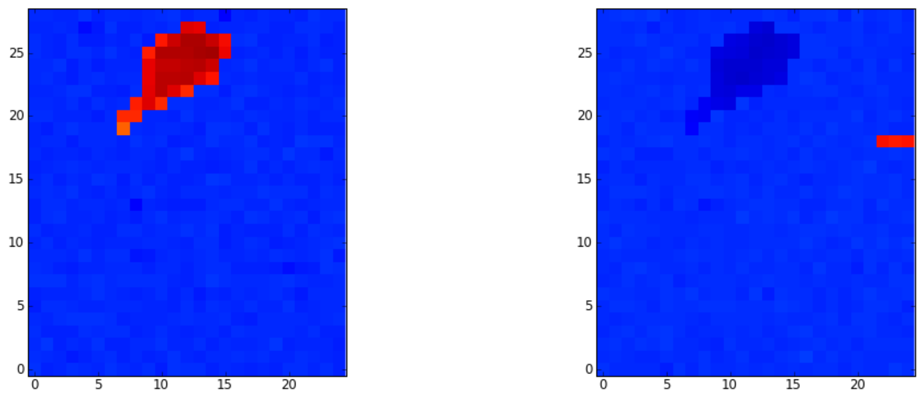


Figure 2. Two snapshots of network oscillatory activity taken shortly after the start. The two areas are well separated, exploiting the oscillatory correlation properties of LEGION, resulting in a segragation-grouping activity.

The LEGION network identifies one or more streams. At this point, an attention mechanism can be deployed, leading to focussing on one of the streams. In refs. 1-3, a possible model is described, which implements a winner-take-all mechanism between streams using a balance between activation and inhibition-of-return for each stream.

Conclusions

In this paper, a framework for modelling human processing of environmental sound was proposed, which could ultimately be used to enhance noise measurement equipment to mimic human perception. In particular, submodels for extracting features and segregating streams using self-organizing maps and LEGION networks were focused on. These submodels could be used as a basis for implementing models for attention focussing and eventually source recognition.

References

[1] D. Botteldooren, B. De Coensel, B. Berglund, M. E. Nilsson, P. Lercher, "Modeling the role of attention in the assessment of environmental noise annoyance," In *Proceedings of the 9th International Congress on Noise as a Public Health Problem (ICBEN)*, Foxwoods, Connecticut, USA (2008).

[2] D. Botteldooren, B. De Coensel, "A model for long-term environmental sound detection," In *Proceedings of the 5th IEEE World Congress on Computational Intelligence (WCCI)*, Hong Kong (2008).

[3] B. De Coensel, D. Botteldooren, B. Berglund, M. E. Nilsson, "A computational model for auditory saliency of environmental sound," *J. Acoust. Soc. Am.* **125**(4):2528 (2009).

[4] B. De Coensel, D. Botteldooren, T. De Muer, B. Berglund, M.E. Nilsson, P. Lercher, "A model for the perception of environmental sound based on notice-events," *J. Acoust. Soc. Am.* (in press).

[5] C. Kayser, C. I. Petkov, M. Lippert, N. K. Logothetis, "Mechanisms for allocating auditory attention: an auditory saliency map," *Current Biology* **15**:1943-1947 (2005).

[6] O. Kalinli, S. Narayanan, "A saliency-based auditory attention model with applications to unsupervised prominent syllable detection in speech," *Proceedings of Interspeech*, Antwerp, Belgium (2007).

[7] T. Kohonen, *Self-Organizing Maps*, Springer-Verlag, Berlin (2001).

[8] D. L. Wang, D. Terman, "Locally excitatory globally inhibitory oscillator networks," *IEEE Trans. Neural Net.* **6**(1):283-286 (1995).

[9] C. von der Malsburg, "The correlation theory of brain function," Max-Planck-Institute for Biophysical Chemistry, Internal Rep. 81-2, 1981.

Perception and Sensation Session 2

Tuesday 10th November

2:00 – 3:30 pm

Chair: Dr Gerie van der Heijden

Synthesizing Visual Textures for Predefined Aesthetic Properties

Stefan Thumfart, Christian Eitzinger

Profactor GmbH, Im Stadtgut A2, 4407 Steyr-Gleink, AUSTRIA,
stefan.thumfart@profactor.at

Abstract

Texture is widely used in areas such as product design or packaging to convey specific information about a product, leaving the designer with the task to find a texture with the desired properties. We present an iterative method that facilitates designers to synthesize visual textures for predefined aesthetic properties such as roughness or elegance.

This method, termed Genetic Texture Synthesis (GTS), relies on recent pixel based texture synthesis methods, which are substantially extended to produce mixed textures. A linear prediction model is used to assess the aesthetic properties of existing texture samples and to guide the synthesis process. Apart from texture mixing, several mutation operators are applied to generate new texture images.

We show that GTS generates new texture images close to a predefined aesthetic target vector.

Introduction

Texture is present in our everyday lives [Sebe and Lew 2001], providing visual cues about real world objects. Consequently the choice of an adequate surface texture is essential in domains such as packaging, product and industrial design [Crilly et al. 2004]. Currently this choice is based upon the experience of the designer, the monitoring of trends or on costly panel tests.

We propose a method, termed *Genetic Texture Synthesis* (GTS), which is capable of supporting a designer's decision by synthesizing new textures with predefined aesthetic properties. GTS is composed of 3 major components:

(1) *texture database*: a database containing a large number of visual textures

(2) a linear *model*, capable of *predicting* the *aesthetic* content of a visual texture from the database

(3) texture *crossover and mutation methods* which generate visual textures from existing ones.

The interaction of these components is illustrated in Figure 1. First the low level texture features, computed for all elements of the texture database, are transformed to aesthetic space using a prediction model. Next, the textures' fitness is scored by comparing the desired aesthetic property vector to the predicted aesthetic properties. Based on their fitness, textures are selected as input for crossover (mixing of 2 textures) or mutation (modification of a single texture) to generate new images. Images which are valid textures (i.e. a non-homogeneous [Sebe and Lew 2001] and stationary [Wei and Levoy 2000]) are added to the texture database. The method stops if (1) a texture close enough to the desired aesthetic property vector is found or (2) an iteration boundary is exceeded.

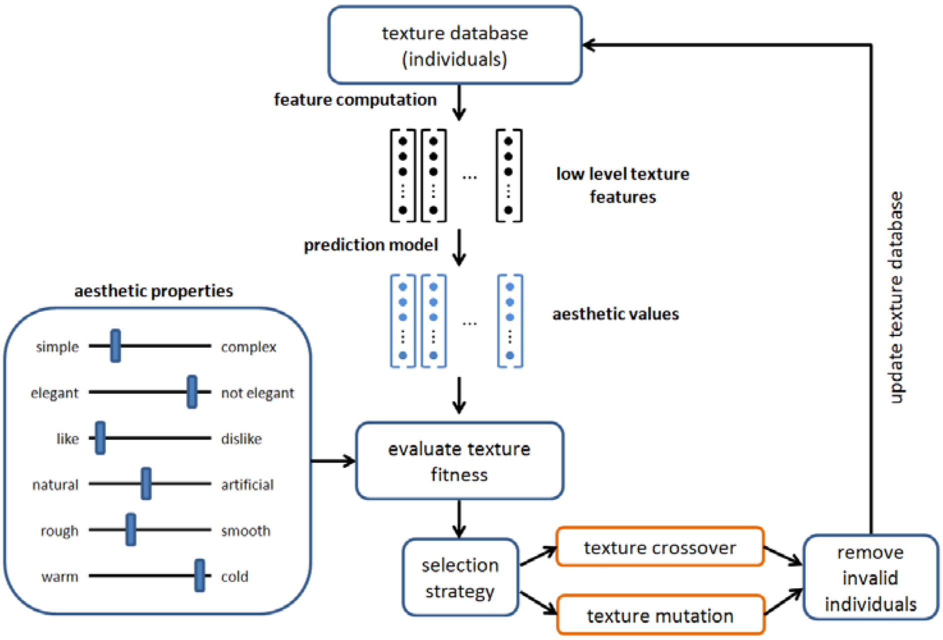


Figure 1: The major components of Genetic Texture Synthesis. The arrows indicate the sequence of processing steps, starting with the feature computation for all elements of the texture database.

Texture Database

Although the texture database is constantly growing, as new textures are added at the end of every GTS-iteration, it is essential to provide a heterogeneous texture selection in the beginning. We collected a wide range of samples ranging from gray-scale textures [Brodatz 1966] to textures provided by an industrial design company. In total the database contains 734 visual textures of size 256 x 256 pixel (Figure 2).

Figure 2: Texture samples from the database.

An Aesthetic Prediction Model

The purpose of the prediction model is to project each individual (=texture sample) from low level feature space to aesthetic space. Prior to the prediction, we extract a set of 188 low level texture and colour features for each individual. We refer the reader to [Thumfart et al. 2009a] for a detailed description of the applied features.

Building the prediction model: Based on the results of a semantic differential experiment (6 core aesthetic antonyms were rated by 19 subjects for 69 textures), a multi-layer regression model for each aesthetic property is built [Thumfart et al. 2009b]. The prediction accuracy in terms of mean average error (MAE) is below 10% of the total range for 5 out of 6 aesthetic properties.

With this reasonably accurate prediction model at hand, we are able to compute the position of each individual in aesthetic space. In aesthetic space an individuals' fitness is computed as its Euclidean distance to the aesthetic target vector (=vector containing the desired aesthetic properties).

Texture crossover and mutation

The idea of genetic algorithms is to improve the fitness of the whole population by recombination (=crossover) or mutation of existing individuals [Mitchell 1997]. We apply image processing methods such as filtering to mutate single textures and pixel based texture mixing to crossover two textures.

Texture mixing: The texture mixing operator is an extension of pixel based texture synthesis approaches (e.g. [Wei and Levoy 2000]), capable of generating a weighted mixture of two input textures as depicted in Figure 3. We select individuals, closest to the aesthetic target vector (=individuals with highest fitness) as input for texture mixing.

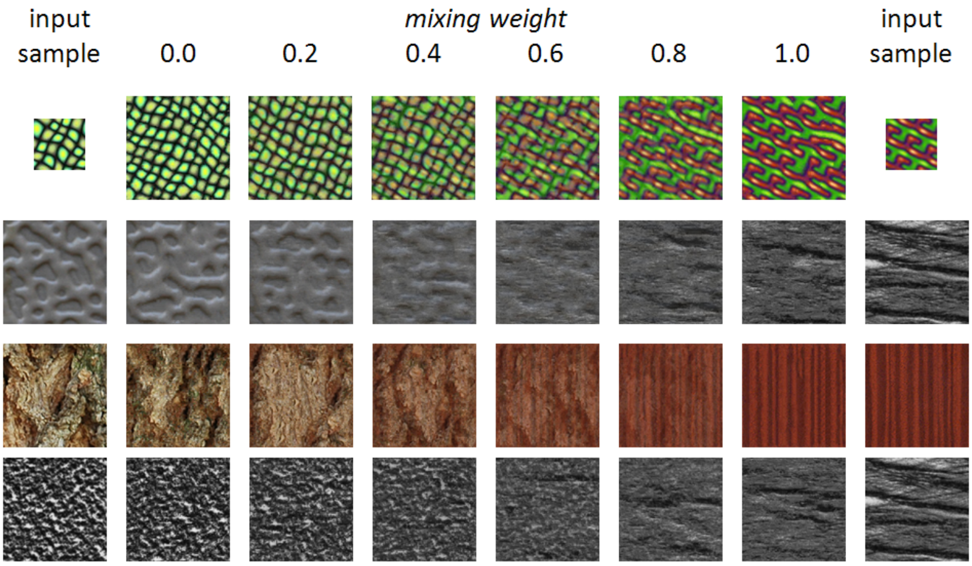


Figure 3: Results of weighted pixel based texture mixing. The mixing weight controls the degree of similarity of the mixing result with the input samples (leftmost and rightmost column).

Texture mutation: A limitation of texture mixing is, that new samples are located inside (or close to) the convex hull of the input samples. Hence it is not possible to generate individuals located outside the convex hull of all existing individuals. We circumvent this limitation by introducing 6 mutation operations which modify the properties of a single individual (Figure 4). The individuals for texture mutation are selected based on their fitness score.

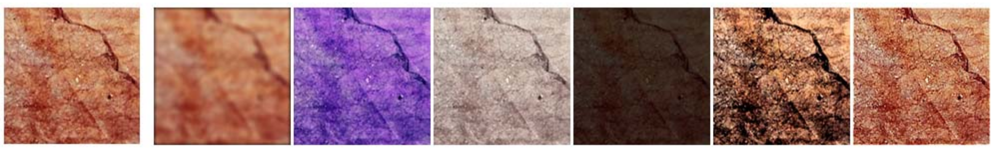


Figure 4: Results of 6 different texture mutation functions for a single individual (leftmost texture).

At the end of each GTS-iteration the new individuals generated by texture mixing or mutation are added to the texture database, given that they are valid (i.e. non-homogeneous and stationary).

Results

We conducted an experiment to demonstrate the performance of GTS, particularly focusing on extrapolation. Hence we aim to generate texture samples close to the corners of a 3-dimensional aesthetic space (*warmth, elegance and like*). The maximum number of iterations was set to 10. During each run 12 individuals were selected for mutation and 3 for crossover, based on their fitness score. As we want to generate individuals outside the convex hull of the existing ones, we decided to sample each dimension of the aesthetic space (range: [-100, 100]) at the points -80 and 80. This results in $2^3 = 8$ target vectors as listed in Table 1.

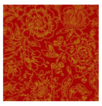
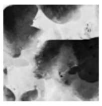
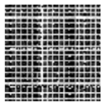
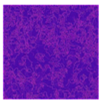
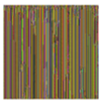
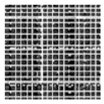
target vector (warm/elegant/like)	(80/80/80)	(80/80/-80)	(80/-80/80)	(80/-80/-80)	(-80/80/80)	(-80/80/-80)	(-80/-80/80)	(-80/-80/-80)
dist (before)	69.07	106.01	95.98	77.65	99.76	115.80	78.47	40.86
NN (before)								
dist (after)	36.44	70.67	38.57	53.05	74.23	90.00	53.11	40.41
NN (after)								
improvement	32.63	35.34	57.41	24.60	25.53	25.80	25.36	0.45
improvement [%]	47.24	33.34	59.81	31.68	25.59	22.28	32.32	1.10

Table 1: Results of GTS. Each column contains the closest individuals (*NN*) to a desired aesthetic target vector, before and after the GTS run. The rows *dist (before)* and *dist (after)* contain the corresponding Euclidean distances. The absolute and relative distance reduction achieved by GTS is given in the last 2 rows.

Although the chosen evaluation task is challenging, as we wanted to create the most "extreme" textures, we could reduce the average distance of the nearest neighbour individuals to the target vector by 31.6 %. Only for a single target no significant improvement could be achieved. A change of the sample points from -80, 80 to -40, 40 lead to a distance reduction of 50.0%.

Acknowledgements

This work was funded by the EC under grant no. 043157, project SynTex. It reflects only the authors' view.

References

[Brodatz 1966] P. Brodatz, *A Photographic Album for Artists and Designers*, New York: Dover Publications, 1966

[Mitchell 1997] T. M. Mitchell, *Machine Learning*, McGraw-Hill, 1997

[Wei and Levoy 2000] L.-Y. Wei, M. Levoy, *Fast texture synthesis using tree-structured vector quantization*, In Proc. of SIGGRAPH'00, pp. 479-488, 2000

[Sebe and Lew 2001] N. Sebe, M. Lew, "Texture features for content-based retrieval", Principles of visual information retrieval, pp. 51-85, 2001

[Crilly et al. 2004] N. Crilly, J. Moultrie, P. J. Clarkson, *Seeing things: consumer response to the visual domain in product design*, Design Studies, vol. 25, issue 6, pp. 547 – 577, Nov. 2004

[Thumfart et al. 2009a] S. Thumfart, W. Heidl, J. Scharinger, C. Eitzinger, *A Quantitative Evaluation of Texture Feature Robustness and Interpolation Behaviour*, CAIP 2009, LNCS vol. 5702, pp. 1154-1161, Springer 2009

[Thumfart et al. 2009b] S. Thumfart, R. HAH Jacobs, E. Lughofer, F. W. Cornelissen, C. Eitzinger, W. Groissboeck, R. Richter, *Modelling Human Perceptions Associated with Visual Textures*, submitted to ACM Transactions on Applied Perception

Perceived Randomness of Surface Textures

K. Emrith[1], P. R. Green[2], M. J. Chantler[1]

[1]School of Mathematical and Computer Sciences, Heriot-Watt University, Scotland, U.K.
[2]School of Life Sciences, Heriot-Watt University, Scotland, U.K.

Abstract

In this study we investigate the intuitive understanding of humans of perceived randomness in naturalistic texture images and their ability to discriminate texture images which differ in appearance due to varying amount of structural information.

While it is known that people are inherently good at finding regularities from temporal sequences of events (such as a series of coin flips), even when the events have been randomly generated, no study have so far investigated the apparent degree of randomness in natural images or images with a naturalistic appearance. Humans generally categorise information as random when they don't find any pattern in it and cannot attribute any meaning. This is generally true when considering sequences of events occurring at given intervals in time, and the identification of patterns is generally used to predict future events (such as market price of stocks). Randomness has thus been regarded as a "special case of structure in information – namely, the case when no structure exists".

Although no formal definition of texture exists, studies have commonly referred to texture images as those that contain repetitive areas with visually similar appearance (also referred to as texture elements, textons or texels). In contrast to randomness in events, randomness in texture images cannot be characterised solely by a lack of structure (e.g. a fractal image), since texture image appearance is also determined by the shape, size, placement and density of the texture elements, and additionally by the illumination and viewpoint conditions. The first objective of this study is thus to investigate how people describe computer synthesised, naturalistic textures that differ in appearance either due to a gradual perturbation in the placement of their texture elements or otherwise in terms of the amount of structural information retained by gradually randomising their Fourier phase spectra. Observers are asked to provide a 'single word' to describe their perception of each image and an analysis of these words is performed to find out for any correlation.

In a second experiment, observers are asked to discriminate between textures that have had their phase spectra randomised. A 2 Alternative Force Choice method is used to capture human judgments. Observers are presented with two pairs of texture images displayed one on top of the other and are required to choose the texture pair that differs by the largest amount based on their perception of randomness. The results from the latter experiment are used to derive perceptual scales reflecting the behaviour of observers for this particular discrimination task.

The Rasch model as a measurement model in affective engineering

Brian Henson

School of Mechanical Engineering, University of Leeds
b.henson@leeds.ac.uk

Introduction

A first attempt is reported at applying the Rasch model to establish measures of people's affective responses to products and stimuli. Data from questionnaires which meet the expectations of the Rasch model are transformed into linear measurement (Rasch, 1960; Luce and Tukey, 1964; Karabatos, 2001). Use of the Rasch model fulfils the requirement for an empirical test of quantitative structure and Rasch's notion of specific objectivity gives independence of measurement from the observer. This resolves problems associated with multivariate analysis of non-linear, ordinal data from semantic differential questionnaires (Stevens, 1946; Wright 1996), and the calibration and standardization problems of studies that use it. The Rasch model has previously been used to obtain measures of purchasers' satisfaction with tractors (Alvarez and Galera, 2001) and perceptions of Iberian ham (Garcia et al., 1996).

Theory

The Rasch model is one model for analysing uni-dimensional constructs that has been developed as part of item response theory (Andrich, 1988; Wilson, 2005). The Rasch model focuses on the probability of the observed responses. The probability of the item response is expressed as a function of the respondent's location, θ (latent attribute) and the item location δ (item scale value). It is the difference between the latent attribute and the item scale value that is important. For dichotomous items (e.g. true or false), when the attribute is the same as the item's scale value, the probability of the response is 0.5. When the latent attribute is greater than the item's value, the probability of a 1 is greater than 0.5 (the respondent is more positive than the item merits) and when it is less, the probability is less than 0.5 (the respondent is more negative than the item).

The Rasch model can be expressed as $\log(P(X_i = 1)/P(X_i = 0)) = \theta - \delta_i$ The unit of measurement of the Rasch model is the logit. When (θ - δ) is 0 logits, the probability of the respondent's latent attribute matching the item is 0.5, and when (θ - δ) is 2 logits, it is 0.88. The dichotomous model is extended to the polytomous case (strongly agree, agree, neutral, etc.) by considering the probabilities of choosing adjacent categories. The reason why the Rasch model is preferable to the other item response models, is that the scale value of items do not vary depending on where the respondent is along the scale.

Rasch analysis of responses to tactile stimuli

In the first experiment, the Rasch model was fitted to people's semantic differential responses to touching a number of stimuli. One hundred participants rated the tactile sensation of leek, buddleia, fleece fabric, glass, peach skin, waxed paper, aluminium, satin, grapefruit, cork and plastic, against twenty adjective pairs on a 7-point semantic differential scale. The adjectives included *raw, hot, pure, tainted* and *grainy*, each paired with a declarative opposite. Principal components analysis (PCA) was carried out to identify uni-dimensional constructs, and stimulus locations against each component were calculated by multiplying the response means by the word loadings. The responses against each of these word pairs were analyzed using the software, RUMM2020 (RUMM).

PCA identified a first component characterized by *good*, *pure*, *pleasant* and *appealing,* and a second characterized by, *seasonal*, *tasty* and *genuine*. The Rasch analysis for component 1 showed that responses to *good* had a poor fit to the model and it was removed from the analysis. The stimulus locations were then calculated for *appealing*, *love* and *pleasant* as the mean average of each person's response to the items. For component 2, the final model established was one in which *seasonal* was split into natural (buddliea, cork, leek, grapefruit, peach and paper), artificial (glass, plastic and aluminium) and textiles (satin and fleece). Item *tasty* exhibited poor fit but removing it made the model worse. By the standard of established instruments used in medical rehabilitation, the fit of component 1 data was acceptable, whilst the fit of component 2 data was poor. The Z scores of the Rasch and PCA-established stimulus values were compared. The product moment correlation between the values for component 1 was 0.91, and for component 2, 0.79.

Rasch analysis of statements about confectionery

In a second experiment, 88 females rated four pieces of wrapped confectionary against eighteen statements on a four-point Likert scale. The statements were established through qualitative consumer research to determine whether the confectionary was considered special and good for sharing. The statements included, for example: *the chocolate in this wrapper would be nice during a coffee break*, and *the chocolate in this wrapper is for children*. A PCA was conducted and the thus identified uni-dimensional constructs were analyzed using RUMM2020.

Two components were extracted. Two items about sharing formed component 2, and the item about the coffee break loaded onto both components. All remaining items loaded onto component 1 and were characterized by *specialness*. Six statements that exhibited good fit with the Rasch model were retained and all others were removed from the analysis. The average position for each stimulus and item were calculated. The positions of the stimuli and statements are shown Figure 1. The responses to the 2 statements loading on component 2 were also analysed, but the fit of the data to the model was poor.

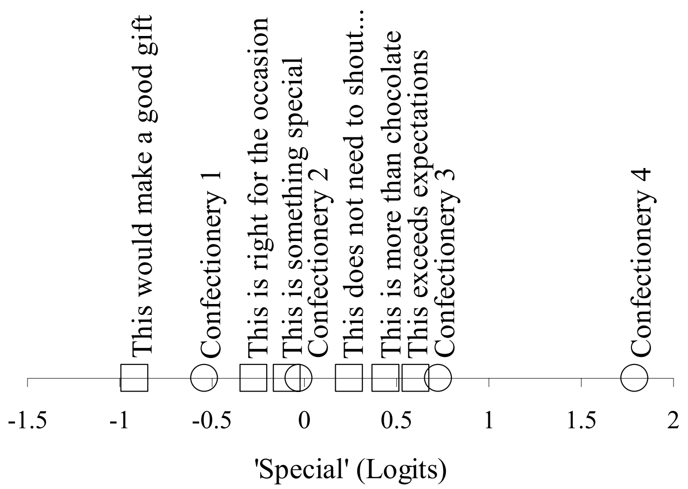


Figure 1. Confectionery scored on a scale of *special*. Squares are locations of items and circles are locations of confectionery.

Discussion and conclusions

The results of the analysis of people's responses when touching natural and artificial stimuli showed that Rasch analysis often gave similar stimulus means to those derived from PCA.
The results of both experiments produced data that was often a poor fit to the Rasch model. This is most likely because the number of participants was small compared to the minimum of 250 that is recommended (Embretson and Reise, 2000). In the experiment that assessed confectionery, it is also speculated that the stimuli were too 'special' relative to the items.

The assessment of confectionery demonstrates how the Rasch model can be used to construct measures of affective responses. In particular, it shows how positions for items and stimuli can be established that are independent of the positions of other items in the study, with benefits for calibration and standardization. In other words, unlike the use of PCA on semantic differential data, the scores of the stimuli should not be affected by which other stimuli are being measured.

References

Alvarez, P., Galera, C. (2001). Industrial marketing applications of quantum measurement techniques. Industrial Marketing Management 30 (1): 13-22.

Embretson, S. and Reise, S. (2000). Psychometric Methods: Item Response Theory for Psychologists Lawrence Erlbaum Associates, Inc ISBN: 0805828192

Garcia, C., et al. (1996). Measuring sensorial quality of Iberian ham by Rasch model. Journal of Food Quality, 19, 397-412.

Karabatos, G. (2001). The Rasch model, additive conjoint measurement, and new models of probabilistic measurement theory. Journal of Applied Measurement, 2, 389-423.

Luce, RD; Tukey, JW, (1964). Simultaneous conjoint measurement: A new type of fundamental measurement. Journal of Mathematical Psychology, 1: 1-27.

Rasch, G., (1960). Probabilistic models for some intelligence and achievement tests. Copenhagen: Danish Institute for Educational Research.

RUMM Laboratory Pty Ltd, www.rummlab.com, last accessed 8 July 2009.
Stevens, S. S., (1946). On the theory of scales of measurement. Science, 103(2684), 677-680.

Wilson, Mark. (2005) Constructing Measures: An Item Response Modeling Approach. Lawrence Erlbaum Associates, ISBN 0805847855.

Wright, B., (1996). Comparing Rasch measurement and factor analysis. Structural Equation Modeling, 3(1), 3-24.

Perception and Sensation Session 3

Tuesday 10th November

4:00 – 5:30 pm

Chair: Ruth Montgomery

Measuring Colour Constancy and Colour Appearance: an Experiment

Alessandro Rizzi [a], Carinna Parraman [b], John J. McCann [c]

[a]*Università degli Studi di Milano, Italy*
(alessandro.rizzi@unimi.it)
[b]*Centre for Fine Print Research, University of the West of England, Bristol, BS3 2JT*
[c]*McCann Imaging, Belmont, MA 02478 USA*

Extended Abstract

Colour sensation does not depend strictly on the light signal conveying colour information, but also depends on the arrangement of the visual array of all signals coming from the scene. Colour constancy is one aspect that contributes to the Human Vision System (HVS) in the formation of colour appearance. In the digital-imaging field the concept of colour constancy is often related with a process of trying to identify the object's reflectance from the light that comes from it. That light is the product of reflectance and illumination. One could separate the reflectance component from the illuminant component, by discounting the illuminant [1]. Although this is claimed to be a useful operation for several applications in computer vision, it is not an accurate description of our human colour appearance mechanism.

Human vision, in fact, does not separate the two components and does not completely eliminate either of the two. HVS developed the ability of normalizing scene appearance across the variation of illuminant and spatial object configuration. In doing this, it is affected not only by the reflectance of the object in the scene and by the spectral content of the illuminants, but also by the spatial array of reflectances and by the spatial non-uniformity of illumination.

The experiment setup

This paper describes some results of an experiment undertaken in 2008 within the European Marie Curie Project CREATE [2] and partially reported at 2009 EI Colour Meeting [3]. We used two sets of identically coloured 3-D Mondrians (see Figure 1). These two still life arrangements are hand-painted coloured blocks using 11 different colours. They are viewed under two different lighting conditions, side by side in the same room at the same time. The first Mondrian was a Low Dynamic Range (LDR), a standard indoor scene with a uniform light using an illumination cube. The second scene was a High Dynamic Range (HDR), with directed spotlights and light reflected from coloured surfaces. We measured appearances of facets of wooden blocks with the same painted surface.

Figure 1 shows the low-dynamyc-range (LDR) scene on the left and the high-dynamic-range (HDR) scene on the right

Measures taken

We used two different techniques to measure appearance: Magnitude Estimation and Artist's Rendition. The first technique used magnitude estimation to assess whether appearances in LDR and HDR Mondrians correlates with the wooden blocks' painted surface. Here, observers were given samples of 'ground truth' and instructions to estimate the magnitude of changes in appearance between different samples of the same paint on different blocks.

The second technique used exactly the same scene. Here we asked an author (CP) to paint the appearances of both the LDR and HDR Mondrians. She used watercolour inks and paints to recreate both LDR and HDR Mondrians on paper. The paintings were created under the same lighting conditions as the participants observed during the original experiment. The hand-painted watercolour captured the observer appearances and rendered them in the watercolour reflectance values.

The important question addressed by both these measurement techniques was whether appearance remained the same in LDR and HDR illumination. Both sets of data show that they do not. Reflectance shows poor to good, correlation with appearance in the LDR case, and poor to bad correlation in the HDR case. We found individual areas with high correlation between reflectance and appearance in both LDR and HDR data. We found that such correlation was frequent in LDR and rare in HDR. Both sets of measurements show that appearance depends on the spatial properties of illumination, as well as reflectance. Edges in illumination cause large changes in appearance, as do edges in reflectance.

Discussion

Both experimental techniques studied the relationship between reflectance, illumination and colour anomalies, such as coloured shadows, how fringes of colours appear and change according to their edges, that are often overlooked when single colours are measured and a whole scene is not considered.

Comparing the watercolour to the photograph of the HDR scene, the coloured shadows and illuminated different coloured faces of the blocks appear to be similar. The most striking difference is the circular reference target at the back of the scene. In the photograph the reference target appears very dark, whereas the colours in the reference target in the painting are clearly perceived. Other areas relate to the reduced gamut of the camera if compared to highly reflective dyes from the drawing inks, which can provide a different estimation of the appearance of the scene. A camera records a scene in a very different manner than the way the human visual system processes the same scene.

There are alternative theories to explain constancy: one discounts the illumination to determine the reflectances of objects; the other synthesizes appearance from edges and gradients in the retinal image. Data from both magnitude estimates and painting reflectance measurements help us to understand that humans do not discount the illuminant.

Summary

Colour constancy is an important subject for colourimetry, computer vision and the study of human vision. Does appearance correlate with the objects reflectance? Both of our measurement techniques, magnitude estimation and painted reproduction, show the same results. They show that there is a higher correlation with reflectance with appearance in uniform illumination. However, in more complex illumination, the results are different. Here, a few areas exhibit perfect constancy, while other areas show very poor correlation with the object's reflectance. Humans synthesize constancy from all the spatial color information in the entire scene, rather than discounting the illuminant.

References

[1] Marc Ebner, *Color Constancy*, The Wiley-IS&T Series in Imaging Science and Technology, 2007

[2] CREATE 2008, University of the West of England, October 2008, http://www.create.uwe.ac.uk

[3] C. Parraman, A. Rizzi & J. J. McCann, "Separating the effects of glare from simultaneous contrast in HDR images", Proceeding IS&T/SPIE Electronic Imaging, 6806-9, 2009.

How many surfaces in natural scenes can be identified by their colour?

David H. Foster,[1,*] Iván Marín-Franch,[1,**] Kinjiro Amano,[1] and Sérgio M. C. Nascimento[2]

[1]School of Electrical and Electronic Engineering, University of Manchester, Manchester M60 1QD, UK
[2]Department of Physics, Gualtar Campus, University of Minho, 4710-057 Braga, Portugal
[*]Corresponding author: *d.h.foster@manchester.ac.uk*
***Current address: Department of Biomedical Sciences and Human Oncology, University of Turin, Turin 10126, Italy*

Introduction

We perceive the different reflecting properties of surfaces as differences in colour. These differences allow surfaces in natural scenes to be discriminated and, potentially, uniquely identified, independent of accidents of position. But there are two physical limits to this process. First, the light reflected from a surface changes with changes in the spectrum of the illumination, and these changes cannot be fully discounted by observer adaptation, so the apparent colour of a surface need not be constant. Conversely, under the same illumination, light reflected from different surfaces can have the same apparent colour, a phenomenon known as metamerism [1]. Given this ambiguity, how many surfaces in a natural scene can, in principle, be uniquely identified by their colour?

In this work, information-theoretic methods were used to estimate the information retrieved by an observer from a scene under different natural illuminations, and a least upper bound on that estimate, the information available. From the information retrieved, the average number of distinct identifiable points per scene was obtained, with each point representing a surface element. Although seemingly indirect, this method has the advantage that it accommodates more general signal dependencies than linear ones.

For a pair of daylight illuminants with correlated colour temperatures (CCTs) of 25000 K, corresponding to blue skylight, and 4000 K, corresponding to sunlight, the information retrieved by an observer, averaged over 50 natural rural and urban scenes, was about 15.2 bits, equivalent to an average of 3.6×10^4 distinct identifiable points per scene. Even without taking into account noise at receptoral and post-receptoral levels, this estimate is much smaller than the estimated average number of discriminable colours, about 2.7×10^5, available in single images of natural scenes [3].

Methods

Calculations were based on data generated from a set of 50 hyperspectral images of natural rural and urban scenes. Each hyperspectral image had dimensions $\leq$ 1344×1024 pixels and spectral range 400–720 nm in 10-nm steps, providing an effective spectral reflectance $r(\lambda; x, y)$ at each wavelength λ and point (x, y) in the scene. This effective spectral reflectance was obtained by dividing the spectral radiance of the image by the spectral radiance of a small neutral (Munsell N5 or N7) reference surface embedded in the scene and then multiplying by the known spectral reflectance of the surface. The effect of a different daylight was simulated by multiplying $r(\lambda; x, y)$ at each point (x, y) by the chosen illuminant spectrum $e(\lambda)$. This procedure is not intended to model geometric changes in the scene as the sun moves across the sky, merely the effects of a change in incident spectrum at any particular surface element. For further details, see [4].

In simulations, scenes were illuminated separately by two daylight illuminants $e_1(\lambda)$ and $e_2(\lambda)$, with correlated colour temperatures of 25000 K and 4000 K, and, for comparison, two daylight illuminants with closer CCTs of 4000 K and 6500 K. Other CCTs could have been considered, but 25000 K and 4000 K define useful practical limits in the CIE system [5].

Triplets of cone responses (l, m, s) at each point in each image of each scene were calculated according from the Stockman and Sharpe [7] estimates of corneal cone spectral sensitivities $\bar{l}(\lambda)$, $\bar{m}(\lambda)$, and $\bar{s}(\lambda)$. From the empirical distribution of these triplets (l, m, s), estimates of the information available were obtained using a modified version of a nearest-neighbour estimator of the mutual information due to Kozachenko and Leonenko [8]. A full account of the estimation procedure is given in [2].

The information retrieved by an observer was assumed to be based on making the best trichromatic matches in order to identify spatially corresponding points across images of a scene under different illuminants. Defined for finite samples of N points drawn from the image, the information retrieved depends on the nature of the post-receptoral coding and the extent of chromatic adaptation. A bias-corrected version of a naïve estimator due to Grassberger [9, Eqns (23) and (27)] was used to estimate the mutual information retrieved post-receptorally as a function of increasing sample size N. A linear transformation T was used to represent post-receptoral interactions [10], and it was optimized for maximum information retrieved by a simplex algorithm with multiple initializations.

The mutual information between two images represents their degree of interdependence, but, more importantly here, it also represents the illuminant-invariant elements of a scene, quantifying the mean number of points that, in principle, are available for reliable identification across the two illuminants. If the mutual information is say a, in bits, then this number is 2^a [11].

Results and Comment

Figure 1 (a) shows, for the daylight illuminants with CCTs of 25000 K and 4000 K, the mean estimated information retrieved post-receptorally $I_K^{\#}(N)$ (circles) as a function of the logarithm of the size N of the sample. The mean estimated information I_{LMS} available at the receptors is indicated by the horizontal line. The bounding value of the discrete entropy of a sample of size N is shown by the dashed line. The estimated asymptote for $I_K^{\#}(N)$ was about 15.2 bits (SD 1.4 bits), which corresponds to a mean of 3.6×10^4 distinct points per scene that can be identified reliably across this illuminant pair. Figure 1 (b) shows the somewhat higher information levels obtained with CCTs of 4000 K and 6500 K.

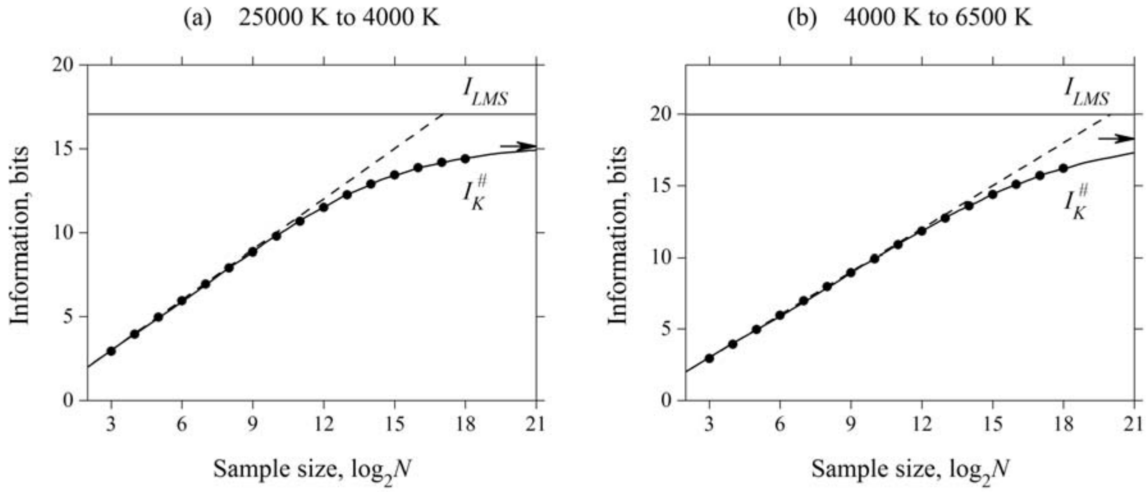


Figure 1. Information available and retrieved by an observer. The mean estimated information available at the receptors I_{LMS} is shown by the horizontal line for two pairs of daylight illuminants with different correlated color temperatures in (a) and (b). The mean estimated information retrieved postreceptorally $I^{\#}_{K}(N)$ (circles) is shown as a function of the logarithm of the size *N* of the sample. The smooth curves are locally weighted linear regressions derived from a best-fitting template from which asymptotic values were estimated, shown arrowed. The dashed line is the bounding value of the discrete entropy of a sample of size *N*. Means were taken over 50 natural scenes.

For both pairs of illuminants, the estimated asymptote for $I^{\#}_{K}(N)$ was about 90% of I_{LMS}. The value of the asymptote is set by the transformation T and the matching procedure. In fact, only with Gaussian distributed signals is nearest-neighbour matching in the space of responses certain to be optimal, and responses here are known to be non-Gaussian [2]. With a scaling of post-receptoral responses by a general linear transformation rather than by von Kries scaling [12], the estimated asymptote for $I^{\#}_{K}(N)$ increased by about 2%.

This analysis was developed for an observer without internal noise. For a real observer, in addition to the noise present at various levels in the visual pathway, there are other uncertainties to do with attention, memory, and the nature of the experimental task that may well affect performance. Therefore, the foregoing estimate of 3.6×10^4 distinct points per scene that can be identified reliably across daylights with CCTs of 25000 K and 4000 K is likely be an overestimate.

Even so, a quite different estimate [3] of the number of colours in single images of natural scenes, based on the CIEDE2000 colour-difference formula with a fixed threshold (and therefore incorporating internal “noise” and other performance uncertainties), has suggested that an observer can discriminate, on average, about 2.7×10^5 colours per image. The fact that this is so much larger than the number of identifiable points per scene suggests a possible physical basis for the observation that colour naming is coarser than colour discrimination.

Acknowledgements
This work was supported partly by the EPSRC (grant nos. EP/B000257/1 and EP/E056512/1), by the FCT (grant POSC/EEA-SRI/57554/2004), and by the Centro de Física da Universidade do Minho.

References

1. *G. Wyszecki and W. S. Stiles,* Color Science: Concepts and Methods, Quantitative Data and Formulae, *2nd ed. (John Wiley & Sons, New York, 1982).*

2. *D. H. Foster, I. Marin-Franch, K. Amano, and S. M. C. Nascimento, "Approaching ideal observer efficiency in using color to retrieve information from natural scenes," J. Opt. Soc. Am. A, (in press) (2009).*

3. *J. M. M. Linhares, P. D. Pinto, and S. M. C. Nascimento, "The number of discernible colors in natural scenes," J. Opt. Soc. Am. A 25, 2918-2924 (2008).*

4. *D. H. Foster, K. Amano, S. M. C. Nascimento, and M. J. Foster, "Frequency of metamerism in natural scenes," J. Opt. Soc. Am. A 23, 2359-2372 (2006).*

5. *CIE, "Colorimetry, 3rd Edition," CIE Publication 15:2004 (CIE Central Bureau, Vienna, 2004).*

6. *D. B. Judd, D. L. MacAdam, and G. Wyszecki, "Spectral distribution of typical daylight as a function of correlated color temperature," J. Opt. Soc. Am. 54, 1031-1040 (1964).*

7. *A. Stockman and L. T. Sharpe, "The spectral sensitivities of the middle- and long-wavelength-sensitive cones derived from measurements in observers of known genotype," Vision Res. 40, 1711-1737 (2000).*

8. *L. F. Kozachenko and N. N. Leonenko, "Sample estimate of the entropy of a random vector " Problems of Information Transmission (Tr. Problemy Peredachi Informatsii. Vol. 23, No.2, pp. 9-16, 1987) 23, 95-101 (1987.).*

9. *P. Grassberger, "Entropy Estimates from Insufficient Samplings" (2008), retrieved* http://arxiv.org/abs/physics/0307138v2*.*

10. *R. L. De Valois, N. P. Cottaris, S. D. Elfar, L. E. Mahon, and J. A. Wilson, "Some transformations of color information from lateral geniculate nucleus to striate cortex," Proc. Natl. Acad. Sci. U. S. A. 97, 4997-5002 (2000).*

11. *T. M. Cover and J. A. Thomas,* Elements of Information Theory *(John Wiley & Sons, Inc., New York, 1991).*

12. *B. Funt and H. Jiang, "Non-von-Kries 3-parameter color prediction," in* Human Vision and Electronic Imaging VIII (Proceedings of SPIE/IS&T Volume 5007)*, 2003), 182-189.*

Measuring Effects of Wall Colours on Perceived Room Spaciousness

David Elliott, Fiona McLachlan

Akzo Nobel Decorative Coatings, Slough, UK
david.elliott@akzonobel.com

In interior design it is widely held that 'warm' colours are 'advancing' while 'cool' ones are 'receding'. Similarly it is commonly understood that rooms with more light feel larger [1]. Relatively few scientific investigations of these effects have been reported, however. The consensus is that distance effects are not simply related to hue but are more influenced by contrast in brightness and saturation while perceived spaciousness is increased by having lighter room surfaces [2]. It is clear, however, that colours must be studied in context to get reliable results. It is also important to carefully control the colours and the lighting. Here we have adapted previously reported methods using miniature rooms and scale figures [3,4], to investigate systematically the role of colour in perceived spaciousness.

Experiments used miniature rooms of internal dimensions, 31cm by 23cm by 23cm height. The walls were brushed with emulsion paint colours. The floors were all painted the same pale yellow colour (Yellow_loL_loC_2 - see below). The ceilings were the same for all rooms and comprised white card in a picture frame. The ceiling had an aperture of 85mm dia. for the illumination. This was provided by a D65 daylight simulating lamp (Gretag McBeth). One short wall also had an aperture of 85mm, for viewing the interior. A screen masked scene changing from the participant.

The colours were whites, pale greys and very pale through to mid-toned colours, as might be used to decorate interior walls (see Table 1). They fell into four hue groups, Reds, Yellows, Greens and Blues and three lightness/ chroma categories as indicated. Some participants were also shown rooms differing in size (standard, 30% and 15% smaller and 15% and 30% larger in floor area). Walls were painted with Grey #2. These were included to enable a calibration curve of floor area versus scene turning point to be derived.

Participants were asked to rate scenes on a scale of Very Crowded, Crowded, Neither Crowded nor Spacious, Spacious and Very Spacious. Five scenes with different numbers of figures and furniture pieces were used (see figure 1). For the colour tests each participant was asked to look at the five scenes in two different rooms. For the room size variations each participant looked at two scenes, each with the five different sizes of room. In either test the ten cases were presented in a randomised order, which took about 20 minutes. The complete study involved 315 participants and was done in four phases. Phase 2 (225 participants) was carried out with recruits from the general public. The others were done with untrained company employees. Tests on each wall colour and room size were replicated 20 and 10 times respectively. Within each phase the replicates were tested in a randomised order.

The raw data for the colour and size tests were fitted using linear regression to determine the predicted turning points, i.e. the scene index or the room size where perception switched from 'spacious' to 'crowded' (see Figure 2). These turning points were used as the key measures of spaciousness for each room by each participant. Outliers were removed using a statistical test wherein the discarded point was more than 2.6 standard deviations from the mean (giving 99% confidence). On average 1.5 values were discarded per 20 replicates.

Table 1 summarises the average scene number turning points for the different wall colours tested. These specify the room contents when the room is perceived as neither crowded nor spacious. Wall colours giving a more spacious feel to a room would be expected to give a lower value, i.e. a more populated scene would be perceived as the turning point.

Mean turning point values versus room floor area, from the size tests, are shown in figure 3. Unsurprisingly the transition from crowded to spacious occurs at more populated (higher) scene numbers when the room is larger. A unit change in scene index corresponds approximately to a 13% increment in floor area.

The high degree of variability in the perceived turning point limits the confidence in interpreting individual differences between pairs of colours. Nevertheless some interesting observations can be made. The lightest white-painted room gave a turning point significantly below the average value for the study, indicated greater perceived spaciousness, while the most chromatic reds gave values significantly higher turning points, indicating greater perceived crowdedness.

The turning point values are not simply correlated with either hue, lightness, chroma, or saturation. Figure 4, however, shows how they can be fitted approximately with a linear model versus saturation, expressed as chroma divided by lightness (C*/L*). A different slope coefficient, however, is needed for each hue group. This model shows a much higher correlation coefficient (0.71) than seen with the simple colour parameters (< 0.44). In contrast the turning point data for the rooms painted white or grey are not explained by differences in saturation in the same way as seen for the colours. The results correlate better with LRV. The room scenes were generally rated as less crowded/more spacious when the walls are lighter.

. As shown in figure 5, colours in the LoL /HiC category on average gave higher values than those in the LoL / LoC and HiL /LoC categories for all the hue groups. For the pooled data and for the Red hue group the differences are statistically significant. For the other hue groups the differences, taken individually are not statistically significant. In all cases the average results for the two low chroma categories cannot be confidently distinguished.

Our data on evaluations of miniature room scenes indicate that there is a measurable effect of wall colour on perceived crowdedness versus spaciousness. The effect, however, is relatively small. The difference between the colour giving the most crowded perception (the most saturated red tested) and the one giving the most spacious perception (the lightest white tested) corresponded to removing two persons or two items of furniture from the scene. Alternatively the size-crowdedness calibration procedure suggests that this difference equates approximately to a difference in floor area of approximately 10%. By this we mean that the red room would require an increase of floor area by this amount relative to the lightest white room for a scene to be rated as neither crowded nor spacious. With whites and greys the determining factor seems to be lightness. With colours both chroma and lightness appear to be important and the determining attribute seems to be saturation (C*/L*). The difference in perceived crowdedness/spaciousness between the lowest and highest saturation was a change of roughly one item (person or furniture) in the scene, corresponding to a 4% increment in area. The largest effect was seen with red hues. With yellows, greens and blues the differences were not statistically significant, although the trends were consistently in the same direction.

We believe that understanding how room colours might be subtly affecting perceptions of spaciousness would be an interesting topic for future research. Akzo Nobel have commercially exploited the benefits of very light colours in

‘Light&Space’ and ‘Lumitec’ ranges and have patented technology for achieving them [5].

Acknowledgements
The authors would like to thank Emma Seeley of Akzo Nobel and Market Measures Ltd for their help with the external field work.

References
1. ‘Small Spaces; Inspiring Ideas and Creative Solutions’, T. Conran, p.134, Clarkson Potter, 2001.
2. ‘The Human Factors of Colour in Environmental Design: A Critical Review’, L R Beach, B K Wise and J A Wise, NASA Grant Report, NCC 2-404, March 1988.
3. ‘How Big is Dark?’, V Ramkumar and C A Bennett, Proc.Human Factors Society, 23rd Annual Meeting, 1979.
4. A. Baum and G.E. Davis: 'Spatial and Social Aspects of Crowding Perception', Environment and Behaviour, **8** (1976), pp.527 - 544.
5. GB2433514

Colour Reference	Y/C*/H*	Turning point +/-0.36 @ 95%	Colour Reference	Y/C*/H*	Turning point +/-0.36 @ 95%
Blue_hiL_loC_1	83/3.1/185	3.0	Red_hiL_loC_1	83/5.8/19	3.1
Blue_hiL_loC_2	71/7.9/247	3.3	Red_hiL_loC_2	87/2.4/23	3.0
Blue_hiL_loC_3	86/2.1/195	3.1	Red_hiL_loC_3	81/4.0/41	3.3
Blue_loL_hiC_1	63/22/222	3.3	Red_loL_hi_C_1	59/20/15	3.5
Blue_loL_hiC_2	60/26/228	3.0	Red_loL_hi_C_2	60/18/13	3.6
Blue_loL_loC_1	62/2.8/233	2.8	Red_loL_loC_1	63/5.8/32	3.1
Green_hiL_loC_1	81/8.3/111	3.2	Yellow_hiL_loC_1	90/7.0/102	3.0
Green_hiL_loC_2	88/11/109	3.0	Yellow_hiL_loC_2	86/5.8/87	3.0
Green_hiL_loC_3	82/8.4/111	3.3	Yellow_loL_hiC_1	77/50/91	3.6
Green_loL_hiC_1	57/20/183	3.5	Yellow_loL_hiC_2	76/52/90	3.2
Green_loL_hiC_2	54/21/188	3.1	Yellow_loL_loC_1	79/8.0/103	3.3
Green_loL_loC_1	62/7.4/172	3.2	Yellow_loL_loC_2	80/12/81	3.2
White_1	94/1.1/115	2.7	Grey_1	46/0.3/253	3.4
White_2	91/3.7/99	3.6	Grey_2	71/0.3/192	3.0
			Grey_3	68/1.8/259	3.1

Table 1 : CIElab co-ordinates and scene number turning point data (colour tests)

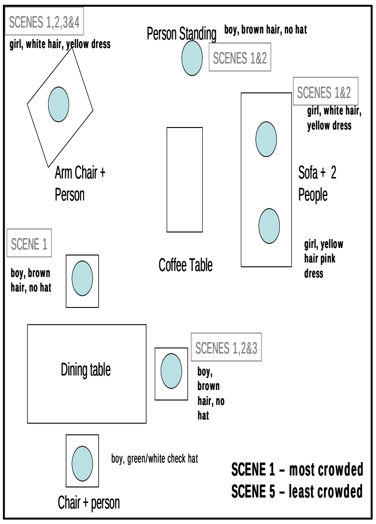


Figure1: Scenes - schematic diagram and photograph from above. Most crowded scene (#1) is shown. Figures and furniture were removed for scenes 2 – 5.

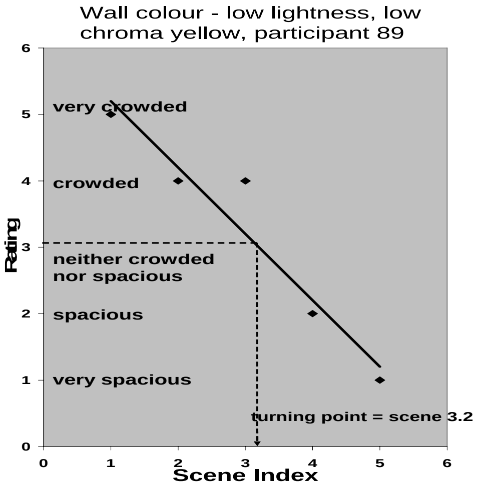


Figure 2. An example of the derivation of scene number turning point

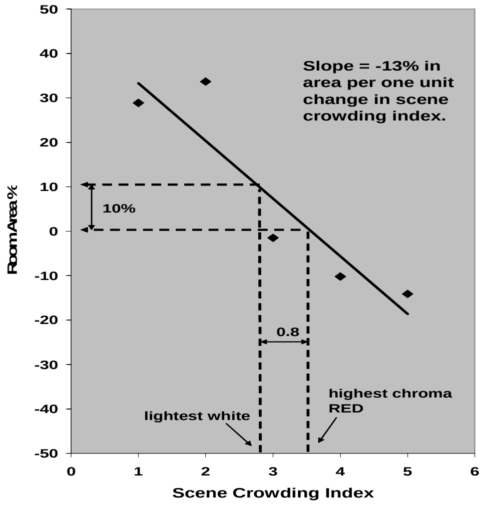


Figure 3 Calibration of scene index versus floor area .

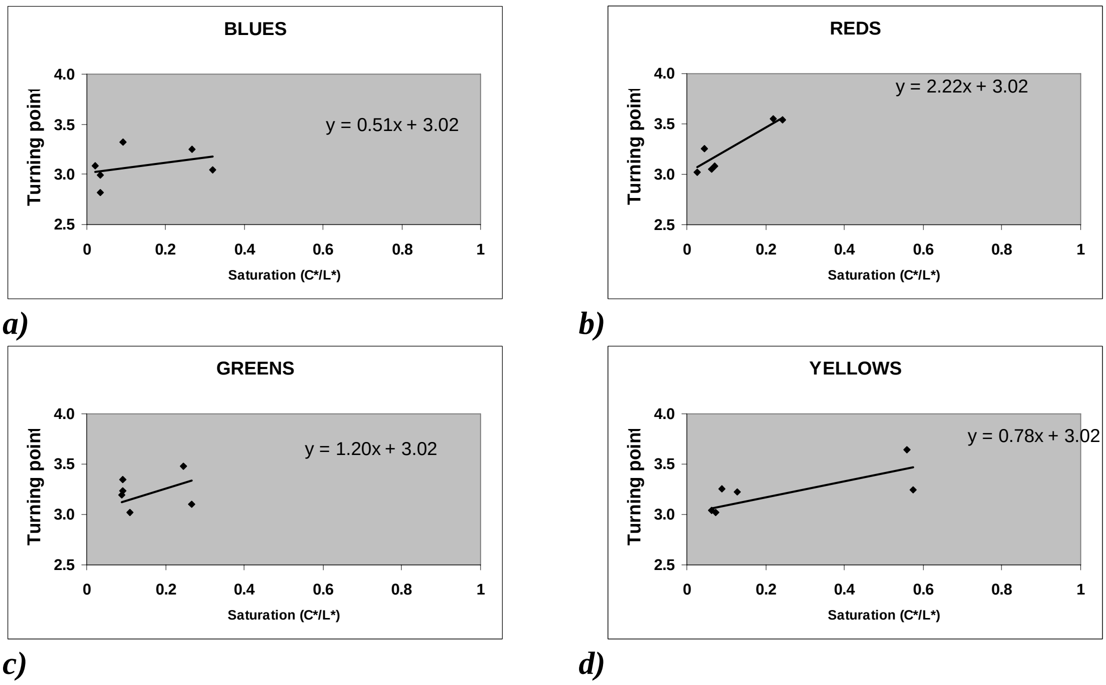


Figure 4 ; Correlation of scene turning point data with saturation

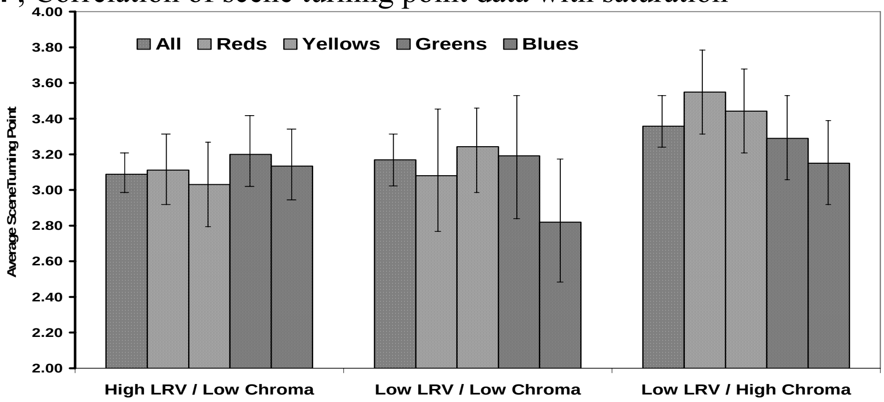


Figure 5 ; Averaged scene turning point data for different lightness/ chroma groups

Perception and Sensation Session 4

Wednesday 11th November

8:45 – 9:45 am

Chair: Dr Gregor Geršak

Time-order effects in timed brightness and size discrimination of paired visual stimuli.

Geoffrey R. Patching, Mats P. Englund and Åke Hellström

Department of Psychology, Stockholm University, Sweden

grp@psychology.su.se

Abstract

The method of paired comparisons is one of the primary psychophysical methods used to obtain the raw data by which to determine the relative discriminability of stimuli. Yet, systematic asymmetries are known to arise in comparison and discrimination of successively presented paired stimuli; termed, time-order effects. In the present work, the focus was on paired comparisons of the brightness and size of visual stimuli. Situations were considered where people are required to compare visual magnitudes, making timed binary choices. An aim was to examine changes in the magnitude and direction of time-order effects with changes in the physical magnitude of the stimuli, overall levels of performance, and with changes in load processing capacity. Increments and decrements in performance were gauged by means of the steepness of psychometric and chronometric functions. Load processing capacity was assessed by dividing integrated hazard functions for stimuli varying congruently along the dimensions of both size and brightness by the sum of those for stimuli varying along either dimension alone. The magnitude of time-order effects was found to increase with increased visual magnitude. Moreover, the variance of time-order effects between participants was found to increase with decreased performance, but the direction and magnitude of such effects were unrelated to load processing capacity. Taken together these findings suggest that time–order effects in timed brightness and size discrimination are perceptual, and the variance of such effects related to the difficulty of the discrimination and alertness of participants. Implications of these findings for common random walk and diffusion models of sensory discrimination are discussed.

MEMORY: Measuring and modelling perceptual space-time

G. M. Cicchini[1] and M. C. Morrone[1]

[1] *Dipartimento di Scienze Fisiologiche, Università degli Studi di Pisa, Pisa, Italy*

Time and space are normally considered to be independent, and are studied typically separately by neuroscientists. However, recent evidence from our laboratory is beginning to show that they are strongly interconnected in the brain [1, 2]. Using standard techniques of adaptation, we have recently shown that neural units sensing the time of events are spatially selective [3]. In the experiment observers adapted to a drifting stimulus within a 12° diameter patch and reported perceived duration of a stimulus either in the same retinotopic or spatiotopic location of the adapter. Perceived duration in the control and the retinotopic locations were near 600 ms, the actual duration of the test. On the other hand events in the spatiotopic location were affected by adaptation and were perceived on average as 456 ms. These results imply that there are multiple timing mechanisms for visual events; these units are selective in real-world coordinates, taking into account the position of the eyes.

If perception of time is mediated by a distributed network of clocks one might wonder how information provided at two locations gets integrated into a single temporal interval. To uncover these processes we investigated temporal perception under strong attentional decrement. In this paradigm subjects were asked to perform concurrently a visual discrimination task (primary task) and a duration discrimination task (secondary task). In one condition the two bars marking the duration, were flashed in two separate locations, in a second condition the two bars were flashed in the same spatial location. We found that shifting attention to perform the primary task induces a strong compression of temporal intervals only if temporal information is present in two separate locations [4]. This indicates that integrating time across space is an attentional demanding process whereas integrating events in a single location occurs despite of attentional deprivation.

Eye movements themselves also affect the perception of time. At the time of saccades, temporal intervals marked by two brief visual stimuli are strongly underestimated. A test interval of 100 ms is judged veridically as long as it is presented far from an eye movement [2]. If the test interval is presented perisaccadically, its duration is compressed down to 50ms. The effect occurs for intervals presented from 150 ms before a saccade to 150 ms after the onset of the eye movement. When subjects to report the perceived timing (relative to two sounds) of a briefly presented visual bar their percept changes perisaccadically. In different epochs of the perisaccadic interval temporal perception was subject to opposite biases [5]. At about the time of the saccadic onset bars were temporally mislocalized 50-100 ms later than their actual presentation. Fifty ms before the saccadic onset, stimuli were perceived as anticipated, producing a consistent inversion of perceived timing. In addition we have shown that if two visual stimuli were presented in this critical interval, their order was inverted. We developed a model that simulated the perisaccadic transient change of neuronal receptive fields and predicted the temporal distortions of human observers. The key aspects of the model are the dynamics of the "remapped" activity and the use of decoder operators that are optimal during fixation, but are not updated perisaccadically [6]. This line of reasoning shares many analogies to the physical case where the observer and the phenomenon to be measured are in different inertial frames of reference that move at different velocities (Special Relativity) and the analogy may be useful to elucidate the phenomenon of perisaccadic distortion of visual perception [7].

Taken together, these experiments show that neural representations of space and time are strongly inter-dependent.

Acknowledgements: This research has been funded by the EU-NEST project MEMORY, FP6 EU-NEST 43236

References

1. Johnston, A., D.H. Arnold, and S. Nishida, *Spatially localized distortions of event time.* Curr Biol, 2006. 16(5): p. 472-9.
2. Morrone, M.C., J. Ross, and D. Burr, *Saccadic eye movements cause compression of time as well as space.* Nat Neurosci, 2005. 8(7): p. 950-4.
3. Burr, D., A. Tozzi, and M.C. Morrone, *Neural mechanisms for timing visual events are spatially selective in real-world coordinates.* Nat Neurosci, 2007. 10(4): p. 423-5.
4. Cicchini, G.M. and M.C. Morrone, *Shifts in spatial attention affect the perceived duration of events.* J Vis, 2009. 9(1): p. 9 1-13.
5. Binda, P., D.C. Burr, and C.M. Morrone. *Spatio-temporal distortions of visual perception during saccades*. in *European Conference in Visual Perception*. 2007. Arezzo: Perception.
6. Cicchini, G.M., P. Binda, and M.C. Morrone, *A model for the distortions of space and time perception during saccades.* Frontiers in Systems Neuroscience. Conference Abstract: Computational and systems neuroscience., 2009.
7. Morrone, M.C., J. Ross, and D.C. Burr, *Keeping vision stable: rapid updating of spatiotopic receptive fields may cause relativistic-like effects*, in *Space and time in perception and action*, R. Nijhawan, Editor. 2008, Cambridge University Press: Cambridge.

Measuring the Impossible

Wednesday 11th November

9:45 am – 3:30 pm

Chair: Dr Kamal Hossain

MINET Expert group report

Once published, the MINET Expert Group Report will be available from the MINET website.

MINET website: http://www.measuringimpossible.net

Round-table discussion

Chair:

Kamal Hossain	*National Physical Laboratory, UK*

Panel members:

Birgitta Berglund	*Stockholm University, Sweden*
Teresa Goodman	*National Physical Laboratory, UK*
Francis McGlone	*University of Liverpool, UK*
Charles Spence	*University of Oxford, UK*

Keynote Paper

Measuring the impossible

Professor Charles Spence, Head of the Crossmodal Research Group

Department of Experimental Psychology, University of Oxford

Introduction

It is currently unclear how to measure people's responses to stimuli that vary along interesting dimensions, such as, for example, in terms of their perceived 'naturalness' or 'pleasantness'. Typically, these are dimensions that cannot be measured physically, since they rely on both the nature of the stimulus being evaluated and on the perceiver. This is especially true when one wants to assess the consumer response under more ecologically valid (i.e., realistic) conditions where many different attributes of the stimulus, not to mention the environment in which the product or stimulus attribute is being evaluated, will vary unpredictably in a number of uncontrollable ways. Given such problems, some people would be tempted to say that attempting to measure the consumer response to real products under realistic testing conditions is like trying to measure the impossible.

Over the last few decades, psychologists and psychophysicists have done a great job of providing researchers with the tools and techniques to allow them to accurately measure people's perception of a variety of relatively simple stimulus attributes (such as the roughness of a sandpaper sample or the pilling of a fabric swatch; e.g., Guest & Spence, 2003a, b; see also Friedman, Hester, Green, & LaMotte, 2008). It is, however, important to note that most such experiments have been conducted under highly-controlled laboratory conditions (i.e., where participants are placed in a dark and silent testing chamber and where the only thing that varies from one trial to the next is the specific stimulus attribute under investigation (and perhaps also the arousal/boredom of the participant concerned). However, the measurement of a consumer's response to some of the more interesting attributes of a real product is still problematic.

I would like to argue that while the challenges that are inherent in this research area may be formidable, the latest cognitive neuroscience techniques, together with our growing understanding of the human brain mean that we are now in a far better position than ever before to look into the mind of the consumer and start both to understand (and, more importantly, to predict) some of the key factors driving their perception and behaviour. In fact, over the last few years, there has been an explosion of research highlighting both the multisensory nature of our everyday perception, and, more importantly, some of the key rules underlying the multisensory integration of the stimuli presented to the different senses (e.g., see Calvert, Spence, & Stein, 2004). While the majority of this research has been conducted using simplistic stimuli under highly-constrained (and artificial) laboratory conditions, scientists have recently started to demonstrate that the same principles of multisensory integration first described in the laboratory can also be used to predict a consumer's response to real products under more ecologically-valid testing conditions (e.g., see Schifferstein & Spence, 2008; Spence, 2008a; Spence & Gallace, in press; Spence & Zampini, 2006, for reviews).

Assessing consumer perception and decision making

Part of the problem here is related to verbal report (Melcher & Schooler, 1996). That is, people typically find it very difficult to explain why they have made the decisions that they have, why they prefer one product over another. Given that so much of our information processing takes place prior to, or below the level of, awareness, we are often unaware of the reasons behind the choices we make. And, what is more, the latest research would appear to show that people's post-choice rationalizing may be nothing more than mere confabulation (Hall, Johansson, Tärning, Sikström, & Deutgen, 2009; Johansson, Hall, Sikström, & Olsson, 2005). The inherent limitations of subjective report can be seen very clearly in the results of a recent study conducted by Gentile, Spiller, and Noci (2007) published in the *European Management Journal*. The authors of this study asked several hundred people to judge which modality was most important to their sensorial experience of a range of popular branded products. According to their participants' subjective reports, taste was the most important attribute of Pringles, sight for Harley Davidson, hearing for the Apple i-Pod, and taste for Gatorade. However, I would like to suggest that the published evidence actually shows that it is sound that is particularly important to people's perception of both Pringles (Zampini & Spence, 2004) and Harley Davidsons (Sapherstein, 1998), that the i-Pod has been so successful as much because of the way it feels in the hand as for the way that it sounds (see Spence & Gallace, in press), and Gatorade has been able to take so much of the market share because of the way it looks (see Garber, Hyatt, & Boya, 2008).

One solution to the problem of verbal report has been to try and develop more objective measures of a consumer's beliefs that do not rely on their having to make a verbal response. For example, the Implicit Association Test (IAT; Greenwald, McGhee, & Schwartz, 1998) provides one such behavioural measure of the degree of association between a number of concepts. The IAT relies not on verbal report, but instead on the speed and accuracy with which people are able to classify a rapidly-presented series of stimuli in order to assess how closely two or more concepts or ideas are associated in the participant's mind. While the IAT was originally developed to test unimodally presented visual stimuli, we have, in recent years, been able to successfully modify the paradigm in order to investigate the nature of the crossmodal associations that people have (e.g., to investigate associations between fragrance and softness, and between fragance and colour; see Demattè, Sanabria, & Spence, 2006, 2007). We have also used the IAT in order to assess how closely consumers associate a particular shape of packaging with specific brand values (Spence & Parise, 2009). Importantly, the IAT can be used to pick up associations between attributes that a person is either unwilling or simply unable to report on verbally (Crisinel & Spence, 2009).

Multisensory perception

A second major problem in terms of trying to measure the consumer response relates to the multisensory nature of human perception. Most of our perceptual experiences result from the multisensory integration of visual, auditory, tactile, olfactory, and sometimes even gustatory cues (Spence, 2002). Research conducted over the last few years has shown that the brain combines the various sensory cues that are available prior to awareness (in order, prumably, to avoid information overload). In the laboratory, the automatic nature of multisensory integration has been demonstrated by illusions such as the McGurk effect, where the speech sound that a speaker is heard to utter can be changed simply by changing the lip-movements that the listener happens to see at the same time (e.g., McGurk & McDonald, 1976). Similar sensory dominance effects have now been found in many different situations (Spence, 2002). So, for example, Morrot, Brochet, and Dubourdieu (2001) conducted an intriguing study in which they showed that people can be fooled into perceiving red wine odours (such as chocolate, tobacco, and dark berry fruits) simply by colouring a white wine red. In our own research, we have been able to show that people's perception of the flavour of a drink can similarly be systematically altered simply by changing the colour of the drink (see Zampini, Sanabria, Phillips, & Spence, 2007; Zampini, Wantling, Phillips, & Spence, 2008). Many of these crossmodal effects appear to occur no matter whether one tests experts or novice assessors (e.g., Parr, White, & Heatherbell, 2003; Teerling, 1992). Elsewhere, we have been able to show that people's perception of the texture of a surface can be modulated by the sounds that they hear when they touch the surface (Demattè, Sanabria, Sugarman, & Spence, 2006).

In terms of the typically sensory testing panel what this means is that consumers are typically only aware of the results of multisensory integration. Hence, when they say that they prefer product X over product Y because it 'feels' nicer, the real difference between the products may actually be in terms of the sound that they make while the consumer touches them, and it is the auditory cues that make the products feel different through a process of multisensory integration (e.g., Guest, Catmur, Lloyd, & Spence, 2002). We have been able to use such insights here at the Crossmodal Research Laboratory in Oxford in order to help a number of companies to successfully modify their products: Making them feel better simply by making them sound different (e.g., Spence, 2008a; Spence & Zampini, 2006). The multisensory approach to product design has, by now, been used to help improve the design of everything from electric toothbrushes (Zampini, Guest, & Spence, 2003) through to deodorant sprays (Spence & Zampini, 2006; see also Schifferstein & Spence, 2008), and from potato chips (and their packages; Spence et al., in press; Zampini & Spence, 2004) through to warning signals for car drivers (Ho & Spence, 2008). This has the result that people are typically unaware of the multisensory contributions to perception. In my laboratory in Oxford, for example, we have been able to show that olfactory cues influence people's judgments of everything from the softness of a fabric swatch (Demattè, Sanabria, & Spence, 2007) through to the physical attractiveness of a person they happen to be looking at on a computer monitor Demattè, Österbauer, & Spence, 2007; Österbauer, Demattè, McGlone, & Spence, 2009)

Individual differences in perception

The majority of laboratory research on perception tends to treat individuals as if they formed part of a homogenous group. That is, individual differences (IDs) in perception and/or performance are typically assumed to reflect noise in one's measurements rather than as reflecting genuine variance in terms of the nature of people's perception. However, over the last few years a growing body of evidence has started to emerge that emphasizes just how important IDs are to explaining people's perception and behaviour in both laboratory and real-world settings (e.g., Bartoshuk, 2000). What is more, these differences would appear, if anything, to be somewhat more pronounced in the case of multisensory perception than for the case of unisensory perception (e.g., see Giard & Peronnet, 1999; Mollon & Perkins, 1996; Shankar, Levitan, & Spence, in press; Stone, Hunkin, Porrill, Wood, Keeler, Beanland, Port, & Porter, 2001; Zampini et al., 2008).

One area where there is currently a lot of applied consumer research interest relates to the existence if IDs in people's need for touch (see Gallace & Spence, in press, for a recent review). Back in 2003, Peck and Childers published a 12-item questionnaire that they argued highlighted the existence of important IDs in people's need for touch (Peck & Childers, 2003a). They described it in terms of *"a preference for the extraction and utilization of information obtained through the haptic system"* (p. 431). Crucially, subsequent research has demonstrated that a person's responses to the questions on their 'need for touch' scale can predict the extent to which differences in the tactile attributes of a product, or its packaging, will influence their perception or, and responses to, that product (see Krishna & Morris, 2008; Peck & Childers, 2003b).

IDs in people's beliefs have also now been shown to affect their multisensory product evaluations as well. So, for example, Levitan and her colleagues recently demonstrated that people vary in terms of their beliefs about the flavour of differently-coloured Smarties (Levitan, Zampini, Li, & Spence, 2008). Crucially, Levitan et al. went on to show that these IDs (e.g., that orange-coloured Smarties taste of orange) influenced their participants' ability to discriminate whether pairs of Smarties actually did taste the same or not. Here, one might think of such results in terms of the well-known placebo effect (e.g., Shiv, Caron, & Ariely, 2005). The available evidence has shown that reliable IDs in multisensory perception can also result from both genetic (see Zampini et al., 2008; though see also Levitan, Crisinel, & Spence, 2009) and cultural factors (see Shankar, Levitan, & Spence, in press). The existence of such reliable IDs in consumer perception, not to mention the age and gender-based differences that also exist (Dalton, Doolittle, & Breslin, 2002; Spence, 2002), is clearly going to make it harder for researchers to derive a meaningful measure of people's perception of a multisensory product or product attribute in the years to come. However, it does at least appear that while people may vary in terms of the particular combinations of stimuli that appear to be maximally effective (e.g., in terms of giving rise to superadditive multisensory interactions in the case of flavour perception; Dalton, Doolittle, Nagata, & Breslin, 2000; Spence, 2008b), they at least use exactly the same rules of multisensory integration to bind them.

Contextual effects on the consumer response

A further problem with measuring the consumer response to a product or product attribute comes from the fact that when put in an experimental setting participant may end up responding not on the basis of what they perceive or think, but on the basis of what they believe the experimenter wants them to say. Such 'experimenter expectancy' effects and response biases are the bain of psychologists (e.g., see Farah, 1988). While innovative psychophysical designs can sometimes be used to distinguish between the perceptual and decisional components to any given effect (e.g., see Green & Swets, 1966; Lau, Post, & Kagan, 1995), it is important to note that it may not always be practical, or even possible to apply such techniques (see Spence, Levitan, Shankar, & Zampini, 2009, on this point). Fortunately, cognitive neuroscience evidence also provides answers to some of these concerns. So, for example, in our work showing that young women rate male faces as being more attractive when presented together with a pleasant odorant (the so-called 'Lynx effect'), we were worried that our participants may have been rating the faces paired with the pleasant, rather than with the unpleasant, odour more highly simply because that was what they believed the experimenter was hoping to find. In our latest research, however, we have been able to demonstrate that the changes in brain activity we see when young female participants look at the male faces in conjunction with the pleasant odour were actually taking place in the part of the brain known to code for facial attractiveness (Österbauer et al., 2009). Such results therefore help to confirm the genuinely perceptual nature of this crossmodal effect of olfaction on vision (see also Li, Moallem, Paller, & Gottfried, 2007). (There is little evidence that participants can please the experimenter by changing the pattern of blood flow in their brains.)

Similarly, neuroimaging research has also been used to help understand the neural mechanisms behind people's differing responses to Coke and Pepsi as a function of whether they know the brand of the drink they happen to be tasting (see McClure, Li, Tomlin, Cypert, Montague, & Montague, 2004). Given that researchers have been working on this problem for more that 60 years without any apparent resolution (e.g., see Davis, 1987; Pronko & Bowles, 1948, 1949), this provides a particularly nice example showing how cognitive neuroscience techniques can, at least under certain conditions, help to resolve long-standing perceptual questions concerning the drivers of a consumer's behaviour (although note that other versions of the Coke vs. Pepsi challenge may not be so easy to resolve by means of neuroimaging, see also Hong, Shieh, Wu, & Chiang, 1987). Of course, one also needs to be aware here that people also tend to be more easily fooled by spurious arguments should the argument be accompanied by a colourful brain image (McCabe & Castel, 2008; see also Heller, 2004).

Another problem that is now becoming increasingly well-recognized relates to the fact that people appear unable to evaluate products in isolation, i.e., without also taking into account any contextual/environmental cues that may be present, even if these cues happen to be completely unrelated to the product under evaluation (e.g., see Green & Butts, 1945; Spence, Shankar, & Blumenthal, in press). So, for example, Spence et al. have recently shown that people's perception of the flavour of foodstuffs (e.g., oysters and ice cream) can be significantly modulated simply by changing the noise that they happen to hear being played in the background. Similarly, there is also growing evidence that a product's packaging can also influence people's perception of the product within (see Raine, 2007; Schifferstein, 2009; Spence et al., in press; "Touch looms large as a sense that drives sales", 1999; Zampini, Mawhinney, & Spence, 2006). One example here comes from Spence et al.'s recent research showing that people rate potato chips as tasty more crispy when they consume them while listening to the noisy rattling of a crisps packet.

Conclusions

In conclusion, assessing the consumers' response to a multisensory product or product attribute in a reasonably ecologically-valid testing context often feels like trying to measure the impossible. Individuals differ, subjective report is untrustworthy, people are unaware of many of the multisensory cues contributing to their perception, they find it impossible to evaluate products in isolation (i.e., without being influenced by the context, both physical and social, in which that testing is taking place), and, for the more interesting stimulus dimensions (such as, for example, pleasantness or naturalness) there is typically no objective means of assessing the extent to which different products or product attributes vary. That said, our growing understanding of the fundamental rules that govern multisensory perception (see Calvert et al., 2004; Ernst & Banks, 2002; Stein & Stanford, 2008), together with the continuing development of increasingly sophisticated measurement techniques (at both the behavioural and neural levels; Lau et al., 1995; Österbauer et al., 2009) are increasingly helping researchers to get a handle on the mechanisms underlying

(McClure et al., 2004), and the key drivers of, the consumer product response. In fact, I would argue that we are currently on the cusp of a pardigm shift in product design, where we will see an irreversible move from the traditional approach to design and design innovation based on intuition, to a more systematic and predictive approach that is based on the emerging cognitive-neuroscience inspired understanding of the mind of the consumer (Spence, 2008c).

References

Bartoshuk, L. M. (2000). Comparing sensory experiences across individuals: Recent psychophysical advances illuminate genetic variation in taste perception. *Chemical Senses*, 25, 447-460.

Calvert, G. A., Spence, C., & Stein, B. E. (Eds.). (2004). *The handbook of multisensory processes*. Cambridge, MA: MIT Press.

Crisinel, A. S., & Spence, C. (2009). Implicit association between basic tastes and pitch. *Neuroscience Letters*, 464, 39-42.

Dalton, P., Doolittle, N., & Breslin, P. A. S. (2002). Gender-specific induction of enhanced sensitivity to odors. *Nature Neuroscience*, 5, 199-200.

Dalton, P., Doolittle, N., Nagata, H., & Breslin, P. A. S. (2000). The merging of the senses: Integration of subthreshold taste and smell. *Nature Neuroscience*, 3, 431-432.

Demattè, M. L., Österbauer, R., & Spence, C. (2007). Olfactory cues modulate judgments of facial attractiveness. *Chemical Senses*, 32, 603-610.

Demattè, M. L., Sanabria, D., & Spence, C. (2006). Cross-modal associations between odors and colors. *Chemical Senses*, 31, 531-538.

Demattè, M. L., Sanabria, D., & Spence, C. (2007). Olfactory-tactile compatibility effects demonstrated using the implicit association task. *Acta Psychologica*, 124, 332-343.

Demattè, M. L., Sanabria, D., & Spence, C. (2009). Olfactory identification: When vision matters? *Chemical Senses*, 34, 103-109.

Demattè, M. L., Sanabria, D., Sugarman, R., & Spence, C. (2006). Cross-modal interactions between olfaction and touch. *Chemical Senses*, 31, 291-300.

Davis, T. (1987). Taste tests: Are the blind leading the blind? *Beverage World*, 3 (April), 42-44, 50, 85.

Ernst, M. O., & Banks, M. S. (2002). Humans integrate visual and haptic information in a statistically optimal fashion. *Nature*, 415, 429-433.

Farah, M. J. (1988). Is visual imagery really visual? Overlooked evidence from neuropsychology. *Psychological Review*, 95, 307-317.

Friedman, R. M., Hester, K. D., Green, B. G., & LaMotte, R. H. (2008). Magnitude estimation of softness. *Experimental Brain Research*, 191, 133-142.

Garber, L. L. Jr., Hyatt, E. M., & Boya, Ü. Ö. (2008). The mediating effects of the appearance of nondurable consumer goods and their packaging on consumer behavior. In H. N. J. Schifferstein & P. Hekkert (Eds.), *Product experience* (pp. 581-602). London: Elsevier.

Gentile, C., Spiller, N., & Noci, G. (2007). How to sustain the customer experience: An overview of experience components that co-create value with the customer. *European Management Journal*, 25, 395-410.

Giard, M. H., & Peronnet, F. (1999). Auditory-visual integration during multimodal object recognition in humans: A behavioral and electrophysiological study. *Journal of Cognitive Neuroscience*, 11, 473-490.

Green, D. M., & Butts, J. S. (1945). Factors affecting acceptability of meals served in the air. *Journal of the American Dietetic Association*, 21, 415-419.

Green, D. M., & Swets, J. A. (1966). *Signal detection theory and psychophysics*. New York: Wiley.

Guest, S., Catmur, C., Lloyd, D., & Spence, C. (2002). Audiotactile interactions in roughness perception. *Experimental Brain Research*, 146, 161-171.

Guest, S., & Spence, C. (2003a). Tactile dominance in speeded discrimination of pilled fabric samples. *Experimental Brain Research*, 150, 201-207.

Guest, S., & Spence, C. (2003b). What role does multisensory integration play in the visuotactile perception of texture? *International Journal of Psychophysiology*, 50, 63-80.

Hall, L., Johansson, P., Tärning, B., Sikström, S., & Deutgen, T. (2009). Magic at the marketplace: Choice blindness for the taste of jam and the smell of tea. *Manuscript submitted for publication.*

Heller, M. A. (2004). Mind and body: Psychology and neuroscience. *Perception*, 33, 383-385.

Ho, C., & Spence, C. (2008). *The multisensory driver: Implications for ergonomic car interface design*. Aldershot: Ashgate Publishing.

Hong, C. Y., Shieh, C. C., Wu, P., & Chiang, B. N. (1987). The spermicidal potency of Coca-Cola and Pepsi-Cola. *Human Toxicology*, 6, 395-396.

Johansson, P., Hall, L., Sikström, & Olsson, A. (2005). Failure to detect mismatches between intention and outcome in a simple decision task. *Science*, 310, 116-119.

Krishna, A., & Morrin, M. (2008). Does touch affect taste? The perceptual transfer of product container haptic cues. *Journal of Consumer Research*, 34, 807-818.

Lau, K.-N., Post, G., & Kagan, A. (1995). Using economic incentives to distinguish perception bias from discrimination ability in taste tests. *Journal of Marketing Research*, 32 (May), 140-151.

Levitan, C. A., Crisinel, A.-S., & Spence, C. (submitted). Assessing the role of sensitivity to 6-n-propylthiouracil (PROP) on the discrimination of the flavor of sugar-coated chocolates. *Chemical Senses*.

Levitan, C., Zampini, M., Li, R., & Spence, C. (2008). Assessing the role of color cues and people's beliefs about color-flavor associations on the discrimination of the flavor of sugar-coated chocolates *Chemical Senses*, 33, 415-423.

Li, W., Moallem, I., Paller, K. A., & Gottfried, J. A. (2007). Subliminal smells can guide social preferences. *Psychological Science*, 18, 1044-1049.

McCabe, D., & Castel, A. (2008). Seeing is believing: The effect of brain images on judgments of scientific reasoning. *Cognition*, 107, 343-352.

McClure, S. M., Li, J., Tomlin, D., Cypert, K. S., Montague, L. M., & Montague, P. R. (2004). Neural correlates of behavioral preference for culturally familiar drinks. *Neuron*, 44, 379-387.

McGurk, H., & MacDonald, J. (1976). Hearing lips and seeing voices. *Nature*, 264, 746-748.

Melcher, J. M., & Schooler, J. W. (1996). The misremembrance of wines past: Verbal and perceptual expertise differentially mediate verbal overshadowing of taste. *Journal of Memory and Language*, 35, 231-245.

Mollon, J. D., & Perkins, A. J. (1996). Errors of judgement at Greenwich in 1796. *Nature*, 380, 101-102.

Morrot, G., Brochet, F., & Dubourdieu, D. (2001). The color of odors. *Brain and Language*, 79, 309-320.

Österbauer, R. A., Demattè, M. L., McGlone, F., & Spence, C. (2009). The influence of odour hedonics on judgments of facial attractiveness: A neuroimaging study. *Manuscript submitted for publication*.
Parr, W. V., White, K. G., & Heatherbell, D. (2003). The nose knows: Influence of colour on perception of wine aroma. *Journal of Wine Research*, 14, 79-101.
Peck, J., & Childers, T. L. (2003a). Individual differences in haptic information processing: The "Need for Touch" scale. *Journal of Consumer Research*, 30, 430-442.
Peck, J., & Childers, T. L. (2003b). To have and to hold: The influence of haptic information on product judgments. *Journal of Marketing*, 67 (April), 35-48.
Pronko, N. H., & Bowles, J. W., Jr. (1948). Identification of cola beverages I: First study. *Journal of Applied Psychology*, 32, 304-312.
Pronko, N. H., & Bowles, J. W., Jr. (1949). Identification of cola beverages III: A final study. *Journal of Applied Psychology*, 33, 605-608.
Raine, T. (2007). Multisensory appeal. *Packaging News*, May, 36-37.
Sapherstein, M. B. (1998). The trademark registrability of the Harley-Davidson roar: A multimedia analysis. http://www.bc.edu/bc_org/avp/law/st_org/iptf/articles/content/1998101101.html#fnB24
Schifferstein, H. N. J. (2009). The drinking experience: Cup or content? *Food Quality and Preference,* 20, 268-276.
Schifferstein, H. N. J., & Spence, C. (2008). Multisensory product experience. In H. N. J. Schifferstein & P. Hekkert (Eds.), *Product experience* (pp. 133-161). London: Elsevier.
Shankar, M. U., Levitan, C. A., Prescott, J., & Spence, C. (2009). The influence of color and label information on flavour perception. *Chemosensory Perception*, 2, 53-58.
Shankar, M. U., Levitan, C. A., & Spence, C. (in press). Does higher level knowledge mediate the interpretation of multisensory cues ? *Consciousness & Cognition*.
Shiv, B., Carmon, Z., & Ariely, D. (2005). Placebo effects of marketing actions: Consumers may get what they pay for. *Journal of Marketing Research*, XLII, 383-393.
Spence, C. (2002). *The ICI report on the secret of the senses*. London: The Communication Group.
Spence, C. (2007). Making sense of touch: A multisensory approach to the perception of objects. In E. Pye (Ed.), *The power of touch: Handling objects in museums and heritage contexts* (pp. 45-61). Walnut Creek, California: Left Coast Press.
Spence, C. (2008a). Auditory product design: New methods for evaluating the influence of changes in product sound on product evaluation. *Proceedings of the Institute of Acoustics*, 30(4), 31-38.
Spence, C. (2008b). Multisensory perception. In H. Blumenthal, *The big Fat Duck cook book* (pp. 484-485). London: Bloomsbury.
Spence, C. (2008c). Sensing the future. In L. Miles (Ed.), *AQR directory & handbook 2008* (pp. 56-60). St. Neots, Cambridgeshire: AQR.
Spence, C., & Gallace, A. (in press). Multisensory design: Reaching out to touch the consumer. *Psychology & Marketing*.
Spence, C., Levitan, C. A., Shankar, M. U., & Zampini, M. (2009). Does food colour influence flavour perception in humans? *Manuscript submitted for publication*.

Spence, C., & Parise, C. (2009). Using the Implicit Association Test to evaluate packaging alternatives. *Manuscript submitted for publication*.

Spence, C., Shankar, M. U., & Blumenthal, H. (in press). 'Sound bites': Auditory contributions to the perception and consumption of food and drink. To appear in F. Bacci & D. Mecher (Eds.), *Art and the senses*. Oxford: Oxford University Press.

Spence, C., & Zampini, M. (2006). Auditory contributions to multisensory product perception. *Acta Acustica united with Acustica*, 92, 1009-1025.

Spence, C., & Zampini, M. (2007). Affective design: Modulating the pleasantness and forcefulness of aerosol sprays by manipulating aerosol spraying sounds. *CoDesign*, 3 (Supplement 1), 109-123.

Stein, B. E., & Stanford, T. R. (2008). Multisensory integration: Current issues from the perspective of the single neuron. *Nature Reviews Neuroscience*, 9, 255-267.

Stone, J. V., Hunkin, N. M., Porrill, J., Wood, R., Keeler, V., Beanland, M., Port, M., & Porter, N. R. (2001). When is now? Perception of simultaneity. *Proceedings of the Royal Society (B)*, 268, 31-38.

Teerling, A. (1992). The colour of taste. *Chemical Senses*, 17, 886.

"Touch looms large as a sense that drives sales" (1999). *BrandPackaging*, 3(3), 39-41.

Zampini, M., Guest, S., & Spence, C. (2003). The role of auditory cues in modulating the perception of electric toothbrushes. *Journal of Dental Research*, 82, 929-932.

Zampini, M., & Spence, C. (2004). The role of auditory cues in modulating the perceived crispness and staleness of potato chips. *Journal of Sensory Science*, 19, 347-363.

Zampini, M., & Spence, C. (2005). Modifying the multisensory perception of a carbonated beverage using auditory cues. *Food Quality and Preference*, 16, 632-641.

Zampini, M., Mawhinney, S., & Spence, C. (2006). Tactile perception of the roughness of the end of a tool: What role does tool handle roughness play? *Neuroscience Letters*, 400, 235-239.

Zampini, M., Sanabria, D., Phillips, N., & Spence, C. (2007). The multisensory perception of flavor: Assessing the influence of color cues on flavor discrimination responses. *Food Quality & Preference,* 18, 975-984.

Zampini, M., Wantling, E., Phillips, N., & Spence, C. (2008). Multisensory flavor perception: Assessing the influence of fruit acids and color cues on the perception of fruit-flavored beverages. *Food Quality & Preference*, 19, 335-343.

Poster session

The abstracts for the poster session start on page 99.

Analysis and Theories

Wednesday 11th November

3:30 – 5:30 pm

Chair: Adj Prof Leslie Pendrill

MINET projects in the context of general measurement and instrumentation science

Ludwik Finkelstein

Measurement and Instrumentation Centre, City University London, UK
l.finkelstein@city.ac.uk

Introduction

The MINET projects have made advances in investigating the measurement of difficult phenomena. They have also developed innovative instrumentation. They have contributed to the solution of significant practical problems.

In addition the projects have addressed challenges facing the Science of Measurement and Instrumentation. The presentation reviews these challenges in outline and proposes that the results of MINET should be used to advance this science.

Science of Measurement and Instrumentation

The Science of Measurement and Instrumentation is the systematically organised body of concepts and principles of measurement and of the instrumentation by which it is performed. The nature and organisation of this science is widely, but not generally, agreed. The presentation reviews the main features of the science.

The widely agreed nature and structure of the science is given in [1], which outlines the development of the science and gives credit to the principal contributors. Reference [2] summarises recent developments and the main challenges and lines of advance of the science.

Principles of measurement

Measurement, in the wide sense, is the assignment by an objective empirical process of symbols to properties of objects and events of the real world, in such a way as to describe them.

Measurement arose at the dawn of material civilisation in the measurement of physical variables. Measurement of physical variable remains the normative paradigm of measurement. However, measurement has become the basic tool of modern thought and is the common way in which we describe the world, reason about it and the basis of many of our actions. Measurement is applied in the social and psychological sciences and in many like applications. The presentation presents briefly the nature and range of these applications.

The presentation distinguishes between strongly defined measurement, that is measurement that conforms to the paradigm of measurement in the physical sciences and weakly defined measurement. The latter is measurement in the wide sense, but does not have all the properties of strongly defined measurement.[3-5]

The MINET projects were concerned mainly with weakly defined measurement.
Weakly defined measurement presents some significant challenges. The presentation outlines briefly some of these challenges.

Among the first of these challenges is the need for a better understanding of the process of formation of the concept of the measurand, which must underlie measurement.

The presentation considers the problems of reliability, generalizability and validity in the formation of measurement scales.

The central importance of nomological networks is examined and emphasised.
The presentation examines the problems that complexity of objects and events under observation involves.

The central importance in all measurement of a well established, universally agreed, maintained and disseminated system of units and standards is considered. It is emphasised that this presents an important challenge to measurement in the wide sense.

The presentation outlines criticisms of the positivist approach to investigations of humans. It will consider the view that all human behaviour is idiographic and not nomothetic. It will review the opinions that observation of humans and human systems is never objective and value free, but is biased by the interests of the observer. It will consider moral objections to treating humans as objects. It will conclude that notwithstanding these objections the positivist approach, based on measurement, has proven its value and potential.

Principles of instrumentation

Instrumentation is changing as a result of the pull of requirements and the push of technical advances. This influences the development of the underlying science.
The requirements are for instrumentation for an ever wider and more diverse range of applications.

The development of information technology means that in modern instrumentation once information is acquired by a sensor system and carried by a conditioned signal, it is further processed by standard methods and equipment of information technology. There is therefore a convergence between principles of instrumentation and principles of information technology.

The range and diversity of modern instrumentation means that the systematic principles of instrumentation must be design orientated.

Among the most important challenges of instrumentation design is the generation of design concepts for the information acquisition system.

The presentation considers the trends and challenges of the principles uf instrumentation.

Conclusions and recommendations

The MINET projects have advanced the measurement of some difficult measurands and developed advanced instrumentation. They have therefore addressed some important challenges of Measurement and Instrumentation Science.

It is therefore desirable that the results of the projects should be integrated into the content and organisation of this science.

Any follow-up of MINET should be planned with the demands of Measurement and Instrumentation Science in mind.

References

[1] L. Finkelstein, "Measurement and instrumentation science An analytical review " *Measurement,* vol.!4, p. 11, 1994.

[2] L. Finkelstein, "Measurement Science – An Examination of Its Current State and Lines of Advance," in Proceedings of *IMEKO XIX World Congress* Lisbon, Portugal, 2009.(*To be published*).

[3] L. Finkelstein, "Widely, strongly and weakly defined measurement," *Measurement,* vol. 34, pp. 39-48, 2003.

[4] L. Finkelstein, "Problems of measurement in soft systems" *Measurement,* vol. 38, pp. 267-274, 2005.

[5] L. Finkelstein, "Widely-defined measurement – An analysis of challenges," *Measurement,* 2009. (*To be published*).

Emerging Paradox and The Role of Context in the Exploration of Human Ability and Performance

M.Layne Kalbfleisch

KIDLAB, George Mason University, Fairfax, VA 22030
mkalbfle@gmu.edu, mlayne55@hotmail.com
Phone: 571-216-2991

We find ourselves in a historical moment where science and technology permit a level of unprecedented and intimate access to our own processes. An underlying feature of this time is our seeming ability to blend the lines between philosophy, intention, and meaning. Yet, as we work to acquire and interpret representations of our selves, senses, thoughts, abilities, and proclivities, a mindful pause brings caution to the exercise. In addition to the overarching paradox of measuring the immeasurable, there are a series of paradoxes arising in the emergence of neurotechnologies and what their data show us about ourselves and the nature of human ability and performance. This presentation will outline a series of these paradoxes, whose vector is aimed at the larger discussion of measuring the impossible.

These paradoxes illustrate that the measurement of our biology, what we expect to find there, and outcomes that follow are inherently more complex than before imagined, as well as more potent, as we consider potential applications and consequences for medicinal diagnosis, treatment, and healing outcome; educational instruction, remediation, and enrichment (Kalbfleisch, in press a); technological and innovative advancement and specificity (Kalbfleisch, in press b), and the command of security environments. The paradoxes to be discussed here include the following: (1) the paradox of public perception of the strengths of neurotechnology and their actual limits (Kalbfleisch, 2008), (2) the nature of paradoxical learners (Kalbfleisch & Banasiak, 2008; Kalbfleisch & Iguchi, 2008) who demonstrate similar behavioral performance on certain tasks, but are supported by altered neural systems (Brar et al; 2009), (3) the paradox of environmental influence on cognition which shows us that the introduction of parametrically manipulated environmental complexity to our senses does not always result in incremental neural modulation in the cortex (Kalbfleisch et al., 2007; Halavi et al., 2009), (4) the paradox of public policies governing education and security, that they are two sides of the same coin, whose challenges are underwritten by the underestimation and identification of talent gone wasted and awry, and, finally, (5) the paradox of our neurobiology - that the brain wants stories (for example, the resting state of the brain characterized by functional magnetic resonance imaging (fMRI) is the brain talking to itself, providing its own narrative about external or internal context), but functions closest to its own nature in the nonverbal domain (Kalbfleisch, 2009).

Because we are squarely in an era where we can more fully and assertively probe our biology for clues about our nature, consideration of these paradoxes provides a touchstone from which to appreciate both the delight and gravity of insights gleaned in this crux. We want to be sure we are setting up strategies for capturing the nature of human ability and performance, not fitting ourselves into experimental precedence for the convenience and certainty of the view.

References

Brar, J., Kalbfleisch, M.L., Chandrasekher, L., Warburton, S.M., Girton, L.E., Hailyu, A., Wolfe, A., Mease, E., Mbwana, J.S., Gallaird, W.D., VanMeter, J.W. (2009). Differences in Response Conflict in Autism Spectrum Disorders. Organization for Human Brain Mapping, San Francisco, CA.

Halavi, M., deBettencourt, M.T., Donohue, M., Kopperman, R., Roberts, J., Serpati, L., Shaw, A., Stoneham, E.T., Kalbfleisch, M.L. Neural systems of color relational complexity. (under review)

Kalbfleisch, M.L. (2009). Fitting the Game to the Brain: Why it Looks Like We Know So Much, But Know So Little. Technology, Neuroscience, & the Nature of Being: Considerations of Meaning, Morality, & Transcendence (Part I). The Nour Foundation. Blackfriars Hall, Oxford University, Georgetown University Symposium Series.

Kalbfleisch, M.L. (in press a). The Neural Plasticity of Giftedness. In L. Shavanina (ed.) International Handbook on Giftedness. Springer Science (pps. 275-293).

Kalbfleisch M.L. (in-press b). Potential constructs and cognitive components in design cognition: Paradigms from educational psychology and neuroscience. In Gero, J. (ed.) Studying Design Cognition. Springer.

Kalbfleisch M.L. (2008). Getting to the Heart of the Brain: Using Cognitive Neuroscience to Explore the Nature of Human Ability and Performance. In L Kalbfleisch (ed.) Special Issue on the Cognitive Neuroscience of Giftedness, Roeper Review, 30(3), 162-170.

Kalbfleisch, M.L., Banasiak, M.E. (2008). ADHD. In Plucker, J.A., Callahan, C. (eds.) Critical Issues and Practices in Gifted Education. Waco, TX: Prufrock Press. pp. 15-30.

Kalbfleisch, M.L., Iguchi, C. (2008). Twice Exceptional Learners. In Plucker, J.A., Callahan, C. (eds.) Critical Issues and Practices in Gifted Education. Waco, TX: Prufrock Press. pp. 707-720.

Kalbfleisch, M.L., Van Meter, J.W., Zeffiro, T.A. (2007). The Influences of Task Difficulty and Response Correctness on Fluid Reasoning. Cognitive Neurodynamics, 1 (1): 71-84. (Online, 2006).

Kalbfleisch, M.L. (2004). The functional neural anatomy of talent. The Anatomical Record, 277B (1), 21-36.

On combining different psychophysical scaling methods

Agnieszka Bialek[1], Krista Overvliet[2,3], Gerie van der Heijden[4]

[1]*National Physical Laboratory, Teddington, UK*
[2]*Departament de Psicología Bàsica, Universitat de Barcelona, Barcelona, Spain*
[3]*Departament de Tecnologies de la Informació i les Comunicacions, Universitat Pompeu Fabra, Barcelona, Spain*
[4]*Biometris, Wageningen University and Research Centre, The Netherlands*

agnieszka.bialek@npl.co.uk

Several psychophysical scaling methods exist which can be used to investigate the human perception of a measurable material property (e.g. colour). However, for more abstract properties such as 'naturalness' an accepted approach has not been established. In the current study this issue is addressed by measuring the perception of naturalness of different materials using four psychophysical methods proven to be effective in measuring known material properties: labelled category scaling (LCS), free-modulus magnitude estimation (FMME), forced choice binary decision (BD) and ranked ordering (RO). For LCS, participants were asked to label each stimulus according to a 7-point scale with labelled categories. For FMME, participants could assign an arbitrary numerical value to the first stimulus, and then assign numbers in direct proportion to the first to the following stimuli; double the value, double the perceived degree of naturalness. For BD each sample would be categorized as either natural or not natural. For RO, the samples are presented individually in a random sequence and ranked from least to most natural with a single ranked position per sample.

Within the literature, the way in which various scaling methods can be combined is not widely discussed or agreed upon. The presented study attempts to define guidelines and make suggestions on how to merge data from different psychophysical scaling methods into a single scale. Several approaches were investigated in the course of this project.

In total 64 participants estimated the degree of naturalness of two different sets of stimuli. The first set consisted of 30 wood and wood-effect samples. The second test set consisted of 44 samples of fabric woven with natural and synthetic threads (e.g. wool and acrylic) in a range of percentage mixes (eg. 25% natural-75% synthetic).

The data shows that the scaling methods are reasonably consistent for the measured dimension of perceived naturalness, which is demonstrated by high correlations, across different methods and participants, which is generally accepted as a powerful validation technique (Gescheider, 1997). However, to be able to use the data from these four different methods as a single input for further analysis their results need to be combined into a single perceptual scale.

Averaging the data of the four different methods after linearly rescaling is a straightforward way to merge them. However, it is not optimal if the scaling methods do not exhibit a linear relationship.

For BD, the number of times that a sample is scored ‘natural’ relative to the total number of observations can be counted. This is, by definition, the probability that the object is being perceived as natural. For LCS the same definition of probability for each category or combination of categories can be applied, however, it is not directly clear which categories should be combined to map the data to the BD-scale. Linear rescaling for FMME can be done by taking the minimum and maximum score for the samples per participant and defining these as zero and one respectively, however this is not a probability in the same way as BD or LCS and the relationship to the BD or LCS scale is unknown. For RO, the perceived degree of naturalness value for a material is strongly dependent on the total test set and the relative order on a 0-1 scale is not a probability. As with FMME, the relationship to the other scales is unknown. A statistically valid method for combining these different scaling methods into a single number for each sample was investigated.

In this presentation, how to establish calibration curves to map the different scales to a single combined (probability) scale will be demonstrated. The methods used include ordinal and logistic regression analysis (Payne et al, 2008). The calibration results will be compared with a total least square regression approach; a linear regression technique permitting consideration of uncertainties associated with dependent and independent variables.

This presentation is an invitation to open discussions on the challenge of merging data derived from different psychophysical scaling methods. The solutions that have been implemented in the EU project MONAT (‘Measurement of Naturalness’), relating the perceived naturalness with physical attributes of the different materials is covered.

Reference

Geschneider, G. A. (1997). Psychophysics: The Fundamentals. Mahwah, New Jersey, Lawrence Erlbaum.
Payne, R.W. et al (2008). Genstat Release 11 Reference Manual. VSN International, Hemel Hempstead, UK.

Acknowledgement

This project was supported by the EU-NEST programme, MONAT project (Measurement of Naturalness, contract number 029000).

Ratio Scales Revisited

Giovanni B. Rossi, Francesco Crenna

DIMEC - Università degli Studi di Genova, Genova, Italy

RATIO SCALES

Ratio scales have been a highly controversial issue between physicists and psychologists in the past. Campbell (1920) distinguished between fundamental and derived quantities: in his view, the former may be directly measured thanks to their internal properties, the latter may be measured only indirectly, thanks to some natural law linking them to some other measurable quantity(ies). Stevens (1946) circumvented this limitation by classifying measurement scales on the basis of their invariance with respect to group transformations. Yet he had to specify empirical relations related to each type of scale. For ratio scales he indicated "equality of ratios" as a distinctive features, but he did not provide any axiomatization, in support of this statement. Successive axiomatisation of non additive ratio scales seem[1] to have concerned magnitude estimation mainly, for which a few formal theories are presently available (Roberts, 1979; Narens, 1996). These theories, despite some differences, basically consider magnitude estimation as a kind of indirect measurement procedure, based on a cross-modality matching between the evoked sensation and some inner reference in persons. If this is the case, we should conclude that ratio scales may only be attained, directly, through an empirical addition operation, or, indirectly, by magnitude estimation.

Yet, in our opinion, there is another possible approach that leads to a *direct* definition of ratio scales, *without assuming physical addition*. This is based on the so called ratio/difference representations (Krantz et al., 1971; Miyamoto, 1983). These representations have been studied to some extent, both theoretically and experimentally, but their consequences have not been, as far as we know, fully exploited. So in this paper we proposed a reconsideration of ratio scales, discussing which kinds of internal properties are really required for achieving them. Then we also mention some preliminary practical applications of these ideas.

EXTENSIVE VERSUS INTENSIVE STRUCTURES

The usual way for attaining a ratio scale is through an empirical *extensive structure*, that may be formally defined as a triple $S_E = (A, \succsim, \circ)$, where A is a set of "objects" (events, persons) manifesting some characteristic, x, under consideration, $\succsim$ is a weak order relation among objects and $\circ$ is an (empirical) addition operation. A representation theorem for such a structure reads

$$a \sim b \circ c \Leftrightarrow m(a) = m(b) + m(c),$$

that is element a is equivalent to the empirical sum of b and c, if and only if the measure of a equals the sum of the measures of b and c.

[1] Due to the vastness of the relevant literature and to the limitation of our knowledge of it, we will avoid any definitive statement, and we will just propose possible interpretations of the state of the art.

The associated scale is *ratio*, since the measure function *m* may safely undergo any similarity transformation

$$m' = \alpha m,$$

with $\alpha > 0$, which basically consists in a change of the measurement unit.
Note that in such a structure there is not a "native", so to speak, relation of ratio. Rather it is inferred by the ratio of measures, which is "meaningful", since the scale is ratio. In other words, we say that the mass of *a* is twice the mass of *b*, if $m(a) = 2m(b)$.
Now a very good question is: *are there empirical structures, having practical, technical and/or scientific relevance, that may give rise to a ratio scale, without having an empirical addition operation?*
If this is the case, such structures would provide a best representation of the measurement of the intensity of a sensation, for example, but also of, say, thermodynamic temperature, which is defined over a ratio scale, but does not seem to have any meaningful empirical addition operation.
Well, such structures actually do exist, although they are perhaps not well known: we will call them *intensive structures*.
So we will (informally) define an *intensive structure* as a triple $S_I = (A, \succsim_d, \succsim_r)$, where *A* is the usual set of objects and $\succsim_d$ and $\succsim_r$ are weak order relations among pairs of objects, referring, respectively, to *difference* and to *ratio*. Now if these two, distinct, orderings exist and if they satisfy some proper compatibility conditions, then it is possible to find a measure function, $m : A \rightarrow \mathrm{R}$, such that the following representations contemporarily holds true:

$$\Delta_{ab} \succsim_d \Delta_{cd} \Leftrightarrow m(a) - m(b) \geq m(c) - m(d),$$

$$a/b \succsim_r c/d \Leftrightarrow \frac{m(a)}{m(b)} \geq \frac{m(c)}{m(d)},$$

where Δ_{uv} denotes the empirical difference between *u* and *v*, and u/v denotes their empirical ratio (not to be confused with the numerical ratio, here denoted by the horizontal line). It is possible to prove that such a measure is on a ratio scale, viz. it safely undergoes similarity transformations, $m' = \alpha m$, with $\alpha > 0$. We have no room here for discussing the associated mathematics, useful references may be found in Krantz et al. (1971/2007) and in Miyamoto (1983). Let us just briefly illustrate the meaning of such a result.
Suppose to present a set of stimuli to a group of persons, asking them to order them both in terms of differences and of ratios of the evoked sensations. If the results of the two orderings are compatible, in a sense that may be precisely specified, then a ratio scale may be applied. Actually this is the environment in which the above result has been obtained. Experimental work was performed, e.g., by Birnbaum (1980), Birnbaum and Veit (1974), Rule and Curtis (1980); early contributions by Garner (1954) and Torgerson are also noteworthy.
Interpretation related to physical measurements seems to be also possible. Consider indeed temperature measurement and the following thought experiment. Suppose that

we have an un-calibrated constant-volume gas thermometer and an un-calibrated mercury-in-glass thermometer. We may use the former for comparing temperatures ratios and the latter for comparing differences. If the two resulting scales are in agreement, a ratio scale results. The underlying basic idea is that the matching is possible if a unique, absolute, zero point is identifiable.

CURRENT DEVELOPMENTS

Our first contribution is in re-interpreting the results concerning ratio/difference representations as a way for attaining a ratio scale by the internal properties of the characteristic under consideration, without needing an operation of empirical addition. This is what we have called an intensive structure.

Secondly, since the original derivation of the representation theorem is quite cumbersome, we are trying and developing a leaner one, considering finite sets of objects. We have discussed elsewhere that this is not a real limitation and greatly simplifies the mathematics, rending it understandable also to the non specialists. Furthermore, a probabilistic reformulation of representation results, necessary for expressing measurement uncertainty, requires, at the current state of the art, the hypothesis of finiteness (Rossi, 2006). Developing a finite theory does not seem to be that straightforward, since, in the case of finite structures it not possible to have, at the same time, a reference scale equally spaced for both differences and ratios. So there seem to be at least two alternative axiomatizations, depending upon which equal spacing is maintained. We will briefly report about this during the workshop.

Moreover, we are also studying the application of the above ideas to experiments for the measurement of loudness. In fact, suppose that an experiment is devised where a group of subjects are asked to rate sounds in term of both loudness differences and loudness ratios and that $m', m'' : A \to \mathrm{R}$ are the corresponding resulting measure functions. If furthermore it is possible to fit data in such a way that, for each $a \in A$,

$$m(a) \cong \alpha_1 \left(m'(a) + \beta \right),$$
$$m(a) \cong \alpha_2 m''(a)^{\gamma},$$

then $m : A \to \mathrm{R}$ constitutes a measure function for loudness on a ratio scale. We are making some experimental work about this in our laboratory, on which we will also report in the workshop (Crenna et al., 2008).

Lastly, we note that the above discussion constitutes a special, but quite important, example of a general problem that seems to have been encountered also in other MINET projects, that is *how to compare different scales for the same quantity*. We hope that also in this regard this communication may result of some interest.

REFERENCES

Birnbaum M H, Veit C T (1974) Scale convergence as a criterion for rescaling, *Perception & psychophysics,* 15, 7-15

Birnbaum M H (1980) Comparison of two theories of ratio and difference judgement, *Journal of Experimental Psychology: General,* 109, 304-319

Campbell N R (1957). *Foundations of science*. New York: Dover. (Original work, *Physics – the elements,* published 1920).

Crenna F, Panero M, Rossi G B 2008 Measurement of perceived sound intensity accounting for individual differences, *12th IMEKO TC7 & TC1 Joint Symposium on Man Science and Measurement, September,* 3-5, Annecy, France, pp. 81-88

Krantz D H, Luce R D, Suppes P, Tversky A, (2007) *Foundations of measurement*, Mineola: Dover (originally published by Academic Press, 1971)

Miyamoto J M (1983) An axiomatization of the ratio difference representation, *Journal of mathematical psychology*, 27, 439-455

Narens L, A theory of ratio magnitude estimation, Journal of mathematical psychology, 40, 109-129 (1996)

Roberts F S (1979) *Measurement theory* Reading, MA: Addison-Wesley.

Rossi, G. B. (2006). A probabilistic theory of measurement. *Measurement, 39,* 34-5

Rule & Curtis 1980 ordinal properties of subjective ratios and differences, *Journal of Experimental Psychology,* 109, 296-300

Stevens S S (1946). On the theory of scales and measurement. *Science*, *103,* 677-680.

Torgerson W S (1961) Distances and ratios in psychophysical scaling, *Acta Psychologica*, 19, 201-205

Keynote Paper

Challenges and Opportunities of Ultra-High Field MRI

Dr Susan Francis

Sir Peter Mansfield Magnetic Resonance Centre, Nottingham University, UK

Over the last three decades, magnetic resonance (MR) systems have pushed toward higher field strength. When introduced in the early 1980s, most of the clinical magnets operated at 0.5 Tesla or less. Today, clinical systems operate at 1.5 or 3 Tesla. Recently there has been a transition to ultra-high field (7 Tesla) MR systems. The Sir Peter Mansfield Magnetic Resonance Centre (SPMMRC), Nottingham University currently operates the only 7T system in the UK.

Ultra–high-field magnets have several advantages; ultra-high field provides better signal to noise ratio allowing images to be acquired at higher spatial resolution to study anatomical and functional features in finer detail, contrast is enhanced due to altered NMR relaxation times, higher field strength allows for the more accurate detection of physiological parameters such as blood flow, and provides improved detection for MR spectroscopy due to higher resolution in chemical shift, for example to study the neurotransmitters glutamate and gamma-aminobutyric acid.

Most current research using ultra–high-field magnets is on brain-related disorders and diseases such as Alzheimer's, multiple sclerosis (MS), Parkinson's, stroke, brain tumours, seizures, epilepsy, and traumatic brain damage. Ultra-high-field scanning of the brain appears to show details, such as MS lesions that are not apparent with lower field magents. At 7T it is now being shown that grey matter is also affected by MS. One new imaging technique which is showing promise at ultra-high field is that of susceptibility-weighted imaging, a blood oxygen level-dependent technique, which may be useful in the context of sub-cortical structures and midbrain structures where it is being applied to study Parkinson's disease.

Ultra-high field has significant advantages for functional magnetic resonance imaging (fMRI). A dramatic increase in the use of fMRI has produced numerous fMRI studies in neuroscience as well as cognitive science. Ultra-high field plays a key role in the development of fMRI using Blood Oxygenation Level Dependent (BOLD) contrast. Both the enhanced susceptibility effect and increased signal synergistically produce better signal to noise ratio of the BOLD signal, resulting in the BOLD signal increasing more than linearly with magnetic field strength. In addition, signals originating from capillaries are more represented in BOLD signal at ultra-high field. This means that measurements at ultra high field allows for more reliable activation to be mapped, and studies performed at much higher spatial resolution allowing for the extraction of higher sensori-motor and cognitive functions. High-field magnets can be integrated with their electroencephalography (EEG) system to obtain functional imaging data and EEG at the same time allowing the combined benefits of superior spatial resolution from their high-field magnet and precise temporal information from EEG.

As the studies continue, ultra–high-field magnet scanning may prove to be an alternative to imaging done with PET or CT. The advantage to the ultra-high-field MRI being that it doesn’t involve ionizing radiation. Thus, studies could be repeated without the worry of the patients reaching their lifetime dose of radiation, which has become a prominent concern.

Cognition & Neuropsychology Session 1

Thursday 12th November

9:45 – 10:45 am

Chair: Dr Gabriele Quinti

Psychophysical and neuroimaging investigations of human touch: discriminative and affective properties

Francis McGlone

Sensation, Perception & Behaviour Group, Unilever R&D, U.K;
Sir Peter Mansfield Magnetic Resonance Centre, University of Nottingham, UK

The skin senses have traditionally been described as conveying tactile, thermal and painful information to the central nervous system, and there is a relatively robust understanding of the peripheral and central neural counterparts of this component of the somatosensory system. It has been known for some time that in mammals there is a class of peripheral nerve fibres (c-fibres) that respond to light mechanical stimulation (stroking) of the body surface, but that in primates, and especially humans, this system has been viewed as vestigial. C-fibres are traditionally classified as either subserving pain and itch sensibility, or autonomic skin functions, but there is increasing evidence that a functional 'pleasure' c-fibre system exists in human skin – notably only found in hairy skin - that responds preferentially to stroking-type stimulation - C-tactile afferents (CT).

Evidence will be presented, employing anatomical, electrophysiological, psychophysical, behavioural and brain-imaging techniques, that demonstrates how the body responds to low force, moving tactile stimulation, and the central representation of this putative affiliative touch system. It is becoming clear that the sense of touch serves much more than a purely *discriminative* function e.g. how hard, or smooth something is, but also conveys information of *affective* valence i.e. how pleasant or rewarding a touch can be, and how vital this sense is to the normal development of the social brain. We are developing a model that extends current opinion about the role of C-fibers, which represents the low-threshold C-mechanoreceptors (CT-afferents) as the counterpart of high-threshold nociceptive C-fibers, with both C-fiber systems dealing with opposing aspects of affective touch, yet underpining a common mechanism for preservation of self and species.

The concept of mapping phenomenal space in somatosensation: Multi-dimensional scaling of pain perception

Dieter Kleinböhl, Jörg Trojan, Rupert Hölzl

The unifying concept maps enable us to depict and analyze physical stimulation patterns, perceptual measures and related brain activations in terms of their spatio-temporal properties. However, likewise approaches to perceived patterns in phenomenal space ('perceptual maps') have been rarely applied to date.

We demonstrate an application of the mapping principle from pain research. Perception of clinical and experimental pain involves sensory and affective perceptual dimensions including specific qualities and percepts, like sensitization, depending on the type of pain and/or the specific neuronal process involved. Multidimensional Scaling is an exploratory method to analyze distance measures of perceptual judgments to gain insight in the underlying dimensionality of a perceptual space. The application of this technique in perceptual mapping is demonstrated for thermal heat pain perception, characterized by several psychophysical methods in healthy subjects and pain patients. In this model, pain perception is characterized by a low dimensional space including static vs. dynamic sensitivity and cognitive evaluative factors.

A first attempt to relate the physical and perceptual maps with brain activation maps is presented and discussed in relation to a recently published methodological approach to integrate these maps (Kriegeskorte et al. 2008; Representational similarity analysis – connecting the branches of systems neuroscience, FSN). We conclude that perceptual maps provide genuinely psychological measures of perceptual processes, complementary to neurophysiologic measurement techniques and ideally suited to link both levels of representation.

References

Becker S, Kleinböhl D, Klossika I, Hölzl R. Operant conditioning of enhanced pain sensitivity by heat-pain titration. Pain 2008; 140(1): 104-14.

Trojan J, Kleinböhl D, Stolle AM, Andersen, OK, Hölzl R, Arendt-Nielsen, L. Independent psychophysical measurement of experimental modulations in the somatotopy of cutaneous heat-pain stimuli. Somatosens Mot Res 2009; 26(1): 11-7.

Trojan J, Stolle A, Kleinböhl D, Mørch CD, Arendt-Nielsen L, Hölzl R. The saltation illusion demonstrates integrative processing of spatiotemporal information in thermoceptive and nociceptive networks. Exp Brain Res 2006; 170(1):88-96.

Trojan, J. et al. Psychophysical ‘perceptual maps’ of heat and pain sensations by direct localisation of CO2 laser stimuli on the skin. Brain Res 1120, 106-113 (2006).

Trojan J, Stolle A, Kleinböhl D, Mørch C, Arendt-Nielsen L, Hölzl R. Sensory saltation in thermoceptive and nociceptive pathways: A spatiotemporal illusion demonstrating integrative processing in sensory networks. Exp Brain Res 2006;170:88-96.

Author

PD Dr. Dieter Kleinböhl, University of Mannheim, Otto-Selz-Institute for Applied Psychology, Laboratory for Clinical Psychophysiology; D-68131 Mannheim. Phone +49 621-181-2111, fax 181-2115, email: kleinboehl@osi.uni-mannheim.de. Date of birth: 15. 09.1960.

Cognition & Neuropsychology Session 2

Thursday 12th November

11:15 am – 12:45 pm

Chair: Prof Francis McGlone

'Mind-reading' approaches: from cognitive neuroscience to clinical applications

Janaina Mourao-Miranda[1,2] and Andre Marquand[2]

1 - Department of Computer Science, Centre for Computational Statistics and Machine Learning, University College London, UK
2 - Department of Clinical Neuroscience, Institute of Psychiatry, King's College London, UK

Recently there has been significant increase of applications of pattern recognition approaches to classify patterns of brain activity elicited by sensory or cognitive processes (Haynes and Rees 2006; Norman et al., 2006) i.e. as 'mind-reading' devices that can predict an individual's brain state. In contrast with the standard approaches used in neuroimaging that try to map cognitive tasks to brain regions, pattern recognition approaches allow the mapping from a pattern of brain activity (e.g. observed fMRI data) to a subject's cognitive state; in other words a "mind reading" approach. The fMRI data are treated as a spatial pattern, and statistical pattern recognition methods (e.g. machine learning algorithms) are used to obtain the mappings. Such algorithms are designed to learn and later predict or classify multivariate data based on statistical properties of the data set. Pattern recognition approaches have been applied in different contexts in neuroimaging. Some studies have applied these approaches to specific regions in the brain, aiming to investigate whether they contain information about a particular cognitive task or process (Haynes et al., 2005). Other studies have investigated the pattern of brain activation distributed over the whole brain (e.g. Mourao-Miranda et al 2005, 2006, 2007; La Conte et al, 2005; Davatzikos et al, 2005, etc), an approach that has also been successfully used in clinical applications (Fu et al. 2007; Marquand et al. 2008). An intermediate approach was used by Kriegeskorte et al. (2006), who proposed scanning the whole brain with a "searchlight" whose contents were analyzed multivariately at each location in the brain.

'Mind-reading' approaches have two important advantages over conventional analysis techniques. First, they explore the multivariate nature of neuroimaging data and take into account the spatial correlation present in the data (each fMRI volume contains information about brain activation at thousands of measured spatial locations), Consequently, pattern recognition can yield greater sensitivity than conventional approaches, which seem to considerably underestimate the information content of functional neuroimaging data (O'Toole et al., 2007; Haynes & Rees, 2006).

Second, once the algorithm is trained with a set of examples (either local or whole brain pattern of brain activations) it can be used to make predictions for a new pattern of brain activation. This is especially important for clinical applications, where previously acquired data can be used to make diagnostic or prognostic predictions for a new subject.

Despite these advantages, pattern recognition approaches also have several drawbacks. For example, interpretation of multivariate brain maps resulting from pattern recognition can be very difficult and some common experimental designs are not well suited to pattern recognition.

Machine learning approaches include a wide range of algorithms, many of which have been successfully applied to neuroimaging, including artificial neural networks, Fisher's linear discriminant, (Mørch et al, 1997), Gaussian naïve Bayes (Mitchell et al., 2004), support vector machines (e.g. LaConte et al., 2005; Mourao-Miranda et al; 2005), logistic regression (Chen et al., 2006), Elastic net (Carroll et al., 2009), Gaussian processes and relevance vector regression (Formisano et al., 2008). These different algorithms are suited to different types of experimental question (e.g. to predict a categorical or a real-valued variable), and confer different advantages (e.g. producing sparse output patterns or probabilistic class predictions).

The presentation will briefly review the current state of pattern recognition methods in neuroimaging and describe examples of clinical applications of these approaches. The presentation will show how these approaches can be used to decode subjective ratings of pain intensity, discriminate between healthy controls and unipolar depressed patients (e.g. Fu et al., 2008; Marquand et al., 2008), and between different patient groups (i.e. individuals with unipolar depression and with bipolar I disorder).

References

Carroll, M.K., Cecchi, G. A., Rish, I., Garg, R., Rao, A. R. Prediction and interpretation of distributed neural activity with sparse models. *Neuroimage*, 2009; 44, 112-22.

Chen, X., Pereira, F., Lee, W., Strother, S., Mitchell, T. Exploring predictive and reproducible modeling with the single-subject FIAC dataset. *Human Brain Mapping*, 2006; 27, 452-61.

Davatzikos C, Ruparel K, Fan Y, et al. Classifying spatial patterns of brain activity with machine learning methods: application to lie detection. *Neuroimage.* 2005;28(3):663-668

Formisano, E., De Martino, F., Valente, G. Multivariate analysis of fMRI time series: classification and regression of brain responses using machine learning. *Magnetic Resonance Imaging*, 2008; 26, 921-34.

Fu C, Mourao-Miranda J, Costafreda S, et al. Pattern classification of sad facial processing: toward the development of neurobiological markers in depression. *Biol Psychiatry.* 2008; 63(7):656-662.

Haynes J. D., Rees G. Decoding mental states from brain activity in humans. *Nat Rev Neurosci.* 2006;7(7):523-534.

Haynes, J. D., G. Rees. Predicting the orientation of invisible stimuli from activity in human primary visual cortex. *Nat Neurosci.* 2005; 8**,** 686-91.

Kriegeskorte, N., Goebel, R., Bandettini, P.. Information-based functional brain mapping. *Proc. Natl. Acad. Sci.* 2006; 103 (10), 3863–3868.

LaConte S, Strother S, Cherkassky V, Anderson J, Hu X. Support vector machines for temporal classification of block design fMRI data. *Neuroimage.* 2005;26(2):317-329.

Marquand A, Mourão-Miranda J, Brammer M, Cleare A, Fu C. Neuroanatomy of verbal working memory as a diagnostic biomarker for depression. *Neuroreport.* 2008; 19(15):1507-1511.

Mitchell, T.M., Hutchinson, R., Niculescu, R.S., Pereira, F., Wang, X., Just, M., Newman, S. Learning to decode cognitive states from brain images. Mach. Learn. 2004 57, 145– 175.

Mørch, N., Hansen, L.K., Strother, S.C., Svarer, C., Rottenberg, D.A., Lautrup, B., Savoy, R., Paulson, O.B. Nonlinear versus linear models in functional neuroimaging: learning curves and generalization crossover. Proceedings of the 15th International Conference on Information Processing in Medical Imaging. 1997.

Mourao-Miranda, J., Bokde, A. L., Born, C., Hampel, H., & Stetter, M. Classifying brain states and determining the discriminating activation patterns: Support Vector Machine on functional MRI data. *Neuroimage*. 2005; 28, 980–995.

Mourao-Miranda, J., Friston, K. J., & Brammer, M. Dynamic discrimination analysis: A spatial-temporal SVM. *Neuroimage.* 2007; 36, 88–99.

Mourao-Miranda, J., Reynaud, E., McGlone, F., Calvert, G., & Brammer, M. The impact of temporal compression and space selection on SVM analysis of single-subject and multi-subject fMRI data. *Neuroimage*. 2006; 33, 1055–1065.

Norman, K. A., S. M. Polyn, G. J. Detre & J. V. Haxby. Beyond mind-reading: multi-voxel pattern analysis of fMRI data. *Trends Cogn Sci.* 2006; 10**,** 424-30.

O'Toole, A., Jiang, F., Abdi, H., Penard, N., Dunlop, J. P., Parent, M. A. Theoretical, statistical, and practical perspectives on pattern-based classification approaches to the analysis of functional neuroimaging data. *Journal of Cognitive Neuroscience*, 2007; 19, 1735-52

Measuring truth with psychological and neuroscientific methods

Hans J. Markowitsch and Angelica Staniloiu

Physiological Psychology, University of Bielefeld, Bielefeld, Germany

hjmarkowitsch@uni-bielefeld.de

The ability to look into the brain in order to detect what a person is really thinking has been the wish of human beings since centuries. A new dimension to the mankind's search for truth was added by the advent of the neuroimaging. The latter has recently become an exciting and sophisticated tool that has been used to describe and identify neural correlates for a variety of mental acts. Technological advances in brain imaging have provided novel methods for distinguishing truth from lie and from false memories (memories, which do not match the external environment, but may frequently have a core of truth). Numerous studies, which focus on differentiating the truth from deception by using brain-imaging technology, have already been published in the scientific literature (see, e.g., the Special Issue on 'Neuroscience and Crime', edited by the first author of the current abstract: *Neurocase 14*, 1-128). Many of these studies point to implications of their findings for the legal system. As results however, differ between studies, relying on such findings for forensic purposes seems premature. A frequently raised question is nevertheless, whether the observed result differences between the studies are due to individual variances in brain organization and circuitry between subjects, or whether they are accounted for by methodological variations such as the employed designs or questions.

We probably performed the first published study in this field (Markowitsch et al., 2000) by asking normal subjects to recall personal life episodes and invent life events, respectively, with as much details and affective-loading as possible. The comparison of the two conditions with functional brain imaging revealed a strong right-hemispheric amygdala response together with further right-hemispheric temporo-frontal activations during the retrieval of true events, while there was mainly an activation of medial portions of the visual association cortex, when invented events were retrieved. Based on these results and earlier findings from the studying of retrieval of old autobiographical memories, we designed a brain imaging study where we compared the retrieval of false and correct memories (Kühnel et al., 2008) – the first imaging study within our EU-project on eyewitness memory. In this study normal subjects watched two short movies of 3-4 minutes duration each, which contained simple scenes. In one of the scenes a young woman tried perfumes in a shop, and in a second scene, a young man engaged in a sequence of simple activities (getting up from his bed in the morning, dressing and eating breakfast). We found that subjects made on the average nearly 45% errors – that is, they indicated that they had seen a scene while in fact they had not, or vice versa, they indicated that they had not seen a scene while in fact they had. Even more surprising was the finding that the brain activations related to true judgments were centered towards the left and right medial prefrontal cortex, while those related to wrong judgments were present bilaterally in the visual association cortex and the precuneus region. The prefrontal activation could reflect processes of monitoring and judgment, while the activations in the visual association cortex and precuneus probably correspond to matching attempts. The precuneus region has been named “the mind’s eye’, indicating that visualization and imagination processes occur in this area.

Another possible, but rarely employed approach for assessing whether a person is telling the truth when claiming that he or she has lost the ability to remember the personal past (or perform in other cognitive domains) is to apply brain imaging methods which permit quantitative measurements of the brain’s glucose metabolism. This can be performed with [^{18}F]fluorodeoxyglucose positron-emission-tomography (FDG-PET), a method that allows to quantify the brain’s glucose metabolism in micromoles per 100 g/min and compare it with that of age- and gender-matched control subjects (e.g., Brand et al., 2009; Markowitsch et al., 2000). By employing this method we found strong neurobiological support for the claims of memory disturbances in patients with dissociative retrograde amnesia, such as a significant decrease of the global glucose metabolism in the brain and an even higher reduction of the glucose metabolism in brain regions involved in synchronizing fact memory with its corresponding emotional load.

Results obtained with brain imaging methods should, however, be complemented by the employment of validated highly structured psychological testing. The so-called lie detection tests (e.g., Tombaugh, 1996) are usually based on probability distributions. In the lie detection test of Tombaugh the subjects first see 50 simple drawings of objects and then they see each of these objects paired with a new (previously unseen) one. As everyone thinks that it not easy to remember such a high number of briefly seen objects, those people engaging in deceiving tend to repeatedly select the wrong object, while over a broad range of intelligence quotient values, subjects wanting to tell the truth name nearly 47 of the 50 objects correctly from the start and perform 100% after the third trial. In addition to lie detection tests, methods for measuring confabulatory tendencies have been developed; we have created a test battery which allows a comprehensive assessment of such tendencies (Borsutzky et al., 2006).

The comparison of the performance across a comprehensive battery of neuropsychological tests offers another modality of assessment and detection of deceit or concealing of the extent of cognitive capacities. For instance, intelligence and overall memory capacity (measured, e.g., by the General Memory Quotient [MQ] of one of the Wechsler Memory Test versions) co-vary, implying that if a person has a high (low) IQ he or she should also possess a high (low) MQ. Individuals, who would want their memory abilities to be interpreted as diminished, might perform more variable or worse in easier than in more complex tests. For instance, it is much easier task to recognize a person within a series of pictures and/or names than to actively generate the name without any cues or hints.

The value of comparative analysis of performance across multiple neuropsychological tests is illustrated by the case of a person, who was accused of simulating memory complaints after having given partly contradictory descriptions of a robbing scene, where he pretended to have been the victim. This person underwent various neuropsychological and memory tests, including lie detection tests. The performance and comparison of the findings of various neuropsychological tests made possible the development of the profile of this person’s intellectual capacities and led to the conclusion that his memory abilities were good and he was only pretending to have poor memory. Although the person initially – when confronted with the test results –

denied any engagement in deceiving, he later admitted that he had invented the entire story in order to receive financial compensation.

In conclusion, these findings suggest that the detection of the truth could be achieved by the employment of a combination of neuropsychological tests and brain imaging methods, especially as the latter become more refined and accepted.

Supported by EU-project FP6-043460 “The Assessment of Eyewitness Memory: A multi-componential, correspondence-oriented approach”.

References

Borsutzky, S., Fujiwara, E. & Markowitsch, H.J. (2006). *Testbatterie zur Erfassung von Konfabulationstendenzen*. Göttingen: Hogrefe.

Brand, M., Eggers, C., Reinhold, N. Fujiwara, E., Kessler, J., Heiss, W.-D. & Markowitsch, H.J. (2009). Functional brain imaging in fourteen patients with dissociative amnesia reveals right inferolateral prefrontal hypometabolism. *Psychiatry Research: Neuroimaging*, in press.

Kühnel, S., Woermann, F.G., Mertens, M. & Markowitsch, H.J. (2008). Involvement of the orbitofrontal cortex during correct and false recognitions of visual stimuli. Implications for eyewitness decisions on an fMRI study using a film paradigm. *Brain Imaging and Behavior, 2*, 163-176.

Markowitsch HJ, Kessler J, Weber-Luxenburger G, Van der Ven C, Albers M, Heiss WD (2000). Neuroimaging and behavioral correlates of recovery from mnestic block syndrome and other cognitive deteriorations. *Neuropsychiatry Neuropsychology and Behavioral Neurology, 13*, 60-66.

Markowitsch, H.J., Thiel, A., Reinkemeier, M., Kessler, J., Koyuncu, A. & Heiss, W.-D. (2000). Right amygdalar and temporofrontal activation during autobiographic, but not during fictitious memory retrieval. *Behavioural Neurology, 12*, 181-190.

Tombaugh, T.N. (1996). *Test of memory malingering (TOMM)*. New York: Multi Health Systems.

Visual processing in natural viewing: Understanding eye movements and brain activity using a fixation-based event-related approach.

J.B.C. Marsman[1,2], J.R. Helmert[3], R.Renken[1,2], F.W. Cornelissen[1,2], S. Pannasch[3] & B.M. Velichkovsky[3]

1: Laboratory of Experimental Ophthalmology, University Medical Center Groningen, Groningen, The Netherlands
2: BCN NeuroImaging Center, University of Groningen, Groningen, The Netherlands
3: Institute of Psychology III, Technische Universitaet Dresden, 01062, Dresden, Germany

Corresponding author: J.B.C.Marsman@med.umcg.nl

Introduction

In everyday life, humans function primarily based on visual input by making eye movements at a fast pace. The way we move our eyes could provide information about how visual information is processed in our brain. The PERCEPT research programme is focused on the investigation of the impact of eye movements on visual processing (Velichkovsky et al., 2006). Despite large individual differences of gaze behaviour, we show that elementary units (i.e. fixations) reveal meaningful information.

Two modes of visual processing

Past research concludes that our visual processing mainly takes place along two routes in the brain (e.g. Milner & Goodale, 1995). First, the dorsal pathway is dealing with ambient processing, i.e. the spatial localisation of objects in a scene. Second, focal processing entails the interpretation of these objects taking place along the ventral route. Recent studies have shown that viewing behaviour can be seen as an overt indicator for the type of processing (Velichkovsky, Joos, Helmert, & Pannasch, 2005). In free viewing of natural images a general trend can be found; on the one hand, fixations are brief in the beginning of presentation, increasing towards a steady equilibrium. On the other hand, early saccadic amplitudes are high and decreasing over presentation time (Pannasch, Helmert, Roth, Herbold, & Walter, 2008).

Fixation based event-related brain activity (FIBER)

Since our vision is crisp when our eyes are stationary, fixations are considered as units of information in visual processing. We investigated cortical responses for individual fixations, which leads to a more ecological approach in neuroscientific research. By combining brain activity (using fMRI) and eyetracking data, we introduce a new technology to perform fMRI analysis based on single fixations. This technique shows the possibility to predict where participants have looked and provides a unique fingerprint for distinct types of fixations in terms of brain response.

Conclusion

Fixation based event-related fMRI analysis enables us to further investigate our visual system in terms of these types of visual processing. Here, we present latest results of eye tracking in combination with this technique, relating brain activity and both ambient and focal viewing behaviour to the time course of free exploration of scenes.

References

Milner, A. D., & Goodale, M. A. (1995). *The visual brain in action*. Oxford, UK: Oxford University Press.

Pannasch, S., Helmert, J. R., Roth, K., Herbold, A.-K., & Walter, H. (2008). Visual fixation durations and saccadic amplitudes: Shifting relationship in a variety of conditions. *Journal of Eye Movement Research, 2*(2), 4, 1-19.

Velichkovsky, B. M. (2002). Heterarchy of cognition: The depths and the highs of a framework for memory research. *Memory, 10*(5/6), 405-419.

Velichkovsky, B. M., Baccino, T., Cornelissen, F. W., Geusebroek, J. M., Hansen, L. K., Hari, R., et al. (2006). *PERCEPT: Perceptual consciousness - explication and testing*. Brussels: EU Commission.

Velichkovsky, B. M., Joos, M., Helmert, J. R., & Pannasch, S. (2005). Two visual systems and their eye movements: Evidence from static and dynamic scene perception. In B. G. Bara, L. Barsalou & M. Bucciarelli (Eds.), *Proceedings of the XXVII Conference of the Cognitive Science Society* (pp. 2283-2288). Mahwah, NJ: Lawrence Erlbaum.

Poster Session

Wednesday 11th November

2:00 – 3:30 pm

Personalised Blood Pressure Monitor

Gregor Geršak and Janko Drnovšek

University of Ljubljana, Faculty of Electrical Engineering, Ljubljana, Slovenia
gregor.gersak@fe.uni-lj.si

Abstract
The concept of personalised instrumentation (PI) is new, as compared to traditional concept of instrumentation, because it focuses on personalisation, subjectivisation and customisation to individual situations, needs, etc. whereas the traditional focuses on generally accepted reference scales, standardised methods and references. There are however many other important areas and phenomena where information such as the one obtained by measurement is required, but at the same time there are no standard references and scales, nor physical or chemical sensors for them. In these cases the available evaluation procedures lead only to highly subjective qualitative information. To solve the problem, these evaluations could be split into associative evaluations, derived from physical or chemical measurements of properties (e.g. oscillometric non-invasive blood pressure measurements) and perception-based evaluations, related to vaguely defined properties (e.g. STAI and TAI questionnaires). To generate meaningful information both categories require PI calibrated against subjective references.
Personalised instrument stands for a measuring device, which along measuring physiological parameters enables also collecting other types of data for a certain patient in a certain psychological, emotional condition at a certain time. Such a device would therefore be a useful tool for the physician to better diagnostically evaluate the state the patient is in, and that in a more holistic manner.
In this paper we are introducing the practical realisation of the concept of PI in the field of home non-invasive blood pressure measurements. The majority of nowadays home-use, GP and clinical practice non-invasive blood pressure measurement devices use the oscillometric principle of measurement. In this paper we are discussing and describing an oscillometric device including also other forms of collecting data of importance for the blood pressure level. The aim of such a PI device is to propose correction factors, which would enable calculative corrections of the measured systolic and diastolic blood pressure levels for a better description of the patient current status.

Keywords: blood pressure, soft metrology, data mining, personal instrumentation

1. INTRODUCTION

The advancements in biomedical science and technology are leading to novel types of medical measuring instrumentation. One of the types is instrumentation whose measuring function is adapted and/or adjusted not only to specific physiological parameters of the patient, but also to various subjective, psychophysical state of the patient. In this paper a novel holistic instrument for non-invasive blood pressure measurement is discussed. During the measurement process the instrument takes into account also other parameters, which are not necessarily of physiological origin but in any case relevant for the blood pressure level, such as emotional stress of the patient, anxiety, white-coat hypertension effect, activities prior the measurements, etc.

Measuring blood pressure non-invasively was first described already in the late 1800s. Different method for blood pressure determination were used and described, i.e. oscillometry was first described already in 1860 by Marey. A couple of decades later today's classical Riva-Rocci and Korotkov auscultation method was described. Nowadays, these methods are the main blood pressure measuring methods used in both clinical and home-care environment. In 1980s the oscillometric method has re-emerged in clinical use. Today it is used with increasing regularity mainly in the scope of semi- or full automatic NIBP devices. The main idea of the oscillometric method is measurement of pressure pulses, which occur in the bladder of a non-invasive cuff wrapped over an artery around the patient's limb. Arterial pulse waves are transmitted via the cuff and measured in form of pressure pulses by a pressure sensor in the NIBP device. The amplitude and shape of pressure pulses vary as the static pressure in the bladder is reduced from above systolic to below diastolic blood pressure. Using different (proprietary) calculative algorithms, systolic and diastolic blood pressures are determined from the pressure pulses' envelope.

The aim of our research is to build a NIBP device, based on oscillometry, but instead of a common empirical calculative algorithm employing regression models gained from data-mining methods. As such it would potentially estimate blood pressure more reliably and accurately also for commonly problematic type of oscillometric measurements (severely hypertensive patients, arteriosclerosis, heart arrhythmia, excessive moving, incorrect body position, measurements in not relaxed state, etc). In this paper we are describing the idea of building an instrument for blood pressure measurement which is along the oscillometric envelope signal including also other auxiliary parameters, like heart rate, ECG, EDA, EMG.

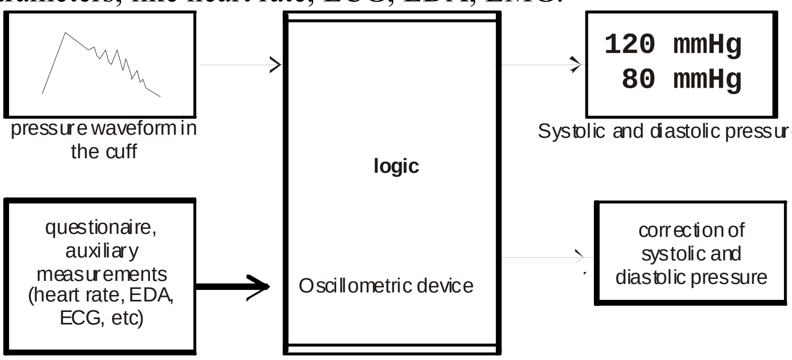


Fig. 1. Principle of personalised oscillometric blood pressure device. By measuring changes in cuff pressure systolic and diastolic blood pressure are determined. Determination is performed by empirical calculative algorithms of the device's logic. Correction factors are determined by other type of input data (psychological questionnaire, heart rate, skin conductivity, ECG signal, level of relaxation, physical activities, current health condition, etc).

2. PERSONALISED INSTRUMENT FOR NON-INVASIVE BLOOD PRESSURE MEASUREMENT

The necessary data for teaching phase of building the regression model was acquired by an upgraded virtual instrument for blood pressure measurement designed in LabVIEW environment for a previous study. The instrument consisted of a data-acquisition module and a data-processing module. In the data- acquisition module the oscillometric envelopes were sampled by means of a cuff and a calibrated pressure transducer. Oscillometric envelopes represented the input data for the data-processing module. The inputs for the teaching phase of the data-processing module were systolic and diastolic values of blood pressure. Values were determined by measuring 20 healthy volunteers using a verified clinically validated commercial NIBP device. Prior to the measurement the volunteers filled-in a questionnaire about their psycho-emotional status, e.g. 5 grade level of relaxation, description of physical activities prior the measurements, current health condition (healthy, acute, chronic illness), heart rate before the measurement, skin conductivity, ECG signal, etc. In the data-processing module the calculation of both systolic (SYS) and diastolic (DIA) blood pressure levels took place. Basic inputs for the regression model, built with data mining tool for the determination of blood pressure levels were pairs of an oscillometric envelope of the pressure pulses and resulting systolic and diastolic blood pressure values, determined within the same measurement.

In the future, calculative corrections of SYS and DIA will be implemented taking into account some general correlations between blood pressure level and psycho-physical state of the patient. E.g. a patient climbing up the stairs to reach the physicians office has elevated blood pressure level or patient sitting in incorrect position would have the blood pressure levels altered. At the moment the teaching group is far too small to draw any conclusions about these correlations. With a larger teaching group the values of the correlation coefficients would be more significantly determined resulting in a more reliably SYS and DIA corrections.

2.1. Acquiring the input signals

Input signals for the model of personalised instrument were oscillometric envelopes of pressure pulses in the cuff, auxiliary and redundant type of input data (STAI and TAI psychological questionnaire, heart rate variability, skin conductivity, ECG signal, level of relaxation, physical activities, current health condition, etc) and resulting blood pressure levels.

For acquiring the oscillometric envelopes and blood pressure determination a measuring system was built. System was built by means of a suitable pressure transducer and a measurement system with high enough sampling frequency. Pressure transducer XFPM 050KPG-P1 (by Fujikura) was used. By means of an A/D card SCB-100TT (by National Instruments) it was connected to a personal computer. In LabVIEW environment a programme for acquiring of the pressure transducer's output, pre-processing and processing of acquired data was written. Output of the programme was a time series of pressure pulses amplitudes versus the cuff pressure, i.e. the oscillometric envelope with sampling frequency 300 Hz. Raw data was processed in LabVIEW environment. It was preconditioned (removing the outliers, preparation for the processing). The oscillations were filtered from the acquired raw signal by using a simple subtractive method. The deflating cuff pressure was fitted by a polynomial function and subtracted from the acquired raw signal, resulting in a time dependant function of the oscillations' amplitudes. Filtering using the fitted ramp is not equivalent to subtracting the base cuff pressure, i.e. the cuff pressure as it would be without oscillations, from the acquired signal. In-time conditioning was included, enabling manual improvement of the envelope shape to exclude errors due to incorrect sampling process, motion artefacts, tremor or cardiovascular abnormalities during the measuring period, etc.

For the purpose of this research ninety real physiological blood pressure signals from 23 healthy volunteers were acquired. Blood pressure levels were determined by means of a commercial clinically validated NIBP device M6 (HEM-7001-E by Omron Healthcare). The acquiring of the raw pressure signal was followed by removing the moving artefacts, outliers and other errors in measurements by the pre-processing module. Using the LabVIEW programme the optimal envelope shape could be adjusted and optimised.

2.2 Building and validating the model

A transfer function has been built by means of regression model, built with data mining tool, which was further used for estimation of blood pressure.
For systolic and diastolic pressure modelling we used open-source machine learning software WEKA, a well-known tool for data mining. Regression models were built on the dataset, which consisted of 125 physiological envelopes of healthy volunteers. Inputs of regression models were built in form of vectors from the envelopes using sampling. We varied the length of the input vector from 10 to 1000. Sampling with different time delays was additionally performed. Outputs of the models are either systolic or diastolic pressure. The following model types were used: simple linear regression, feed-forward neural network (multilayer perceptron) and a model based on support vector regression. The quality of regression models, which we also call predictors, was estimated by means of the following performance measures: root mean squared error (*RMSE*), correlation coefficient (*CC*), and Mean Absolute Error (*MAE*). Because our dataset was of limited size, with an aim of avoiding the overfitting, we used a mechanism called n-fold cross validation in order to estimate the error of prediction (regression).

4. RESULTS AND CONCLUSIONS

Nowadays, the oscillometric devices for blood pressure measurements are widely used in both clinical and home-care environment. Their main advantages are simplicity and straightforwardness of use and high accuracy when measuring a normo-tension patient. On the other hand they tend to develop measuring error when measuring severe hypertension patients, or patients with certain physiological properties (arteriosclerosis, heart arrhythmia). Oscillometry is known to be also quite sensitive to moving artefacts.
In this paper we tried to investigate the possibility of substitution of the simple oscillometric algorithms with more complex ones, which would include also other important data describing the psychophysical state of the patient in order to enable a reliable functionality also in more demanding measuring conditions. Such an oscillometric device, which would estimate blood pressure by means of data mining modelling, should enable estimation of blood pressure for different levels and different amplitudes of oscillometric pulses with sufficient regression accuracy. The concept of personalised instrumentation includes extension of the modelling by adding attributes that describe the person involved in the measurement in more detail (physiological and psychophysical state of the person). Improvement of the regression accuracy is expected, if the modelling would consider certain attributes, which are confirmed by the research medicine as influence factors for hypertension (e.g. age group, arm circumference, emotional stress, white-coat hypertension, etc).

Objective Characterisation of Food Textural Properties in Relation to Sensory Perception

Jianshe Chen,[1]* Malcolm Povey,[1] Andrea Utley,[2] and Yadira Gonzalez[1]
[1] School of Food Science and Nutrition, University of Leeds, Leeds LS2 9JT
[2] Centre for Sport and Exercise Sciences, University of Leeds, Leeds LS2 9JT

Food texture is commonly accepted as the sensory and functional manifestation of the structural, mechanical and surface properties of foods. Textural perception combines visual, somatosensory and auditory sensation throughout the whole food consumption processing (seeing, handling and the oral processing). Therefore, sensory perception of food texture is highly subjective and to quantify such textural features in a more objective way is a big challenge for the food industry. Extensive research work has been conducted by the Leeds Food Physics group on food texture and sensory perception. In this work, we report significant progress recently made in this group: the acoustic characterisation of food crispness and its synchronisation with mechanical examination, and the implications of food stickiness for oral (eating) behaviour.

A crisp food (such as crisps, biscuits, etc) normally has a brittle mechanical structure which fractures easily during eating Such a food material will produce a typical zigzag shaped force-displacement curve, accompanied by a sequential release of acoustic signals, when it fractures (1,2). Figure 1 is an example of synchronised acoustic and mechanical examination of a crisp biscuit. The zigzag force curve corresponds well with the recorded acoustic peaks. For many force drops, there is a bunch of acoustic signals, an indication of a series of minor cracks/fractures. This suggests that acoustic approach could be much more sensitive for crispness characterisation than the more conventional mechanical assessment.

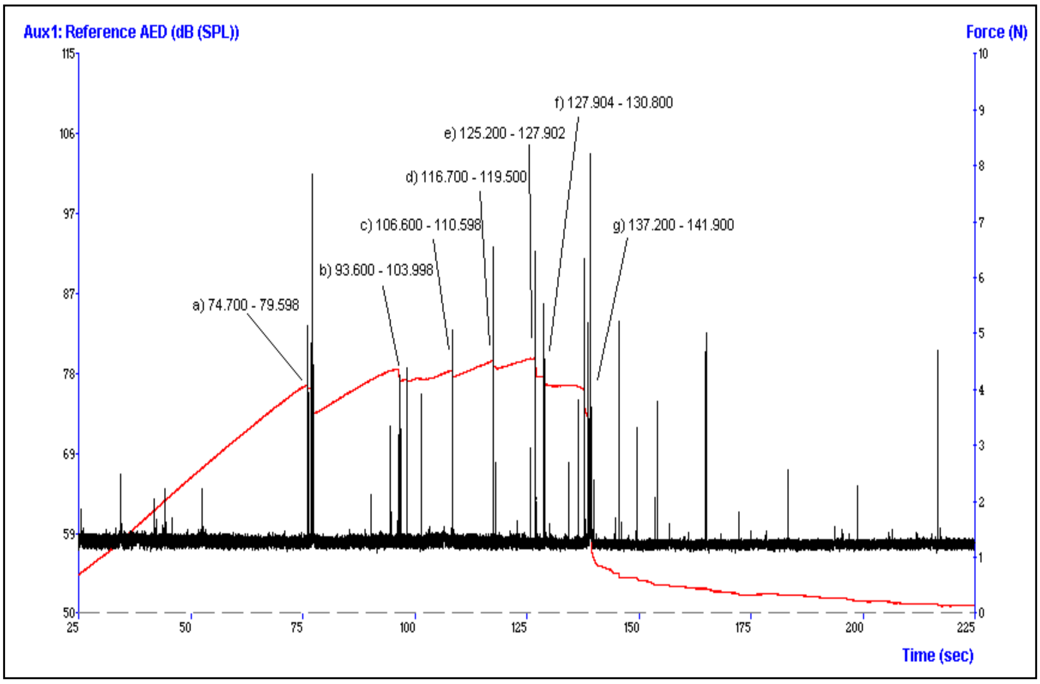


Figure 1. Synchronised acoustic and mechanical characterisation of the fracture of a biscuit (the continuous curve is the force curve, bars are the acoustic signals) (1).

However, many foods that are sensually perceived as crisp do not have a uniform brittle microstructure. Potato chips are typical examples. These foods normally have a brittle and crisp shell but soft, wet and texturally non-crisp interior. The brittle shell can be appreciated for its crisp texture during eating, while the soft wet interior makes it easier for deformation and breaking and for bolus formation. For such materials mechanical tests were found to be infeasible for crispness characterisation, because their force-displacement curves were no longer zigzagged, giving no indication at all of the brittle and crisp sensory feeling. However, passive acoustics could still be valuable for crispness assessment. Figure 2 shows a typical experimental set up for a potato chip, where two microphones are used to recorded acoustic signals of audible range and frequency spectrum of acoustic events.

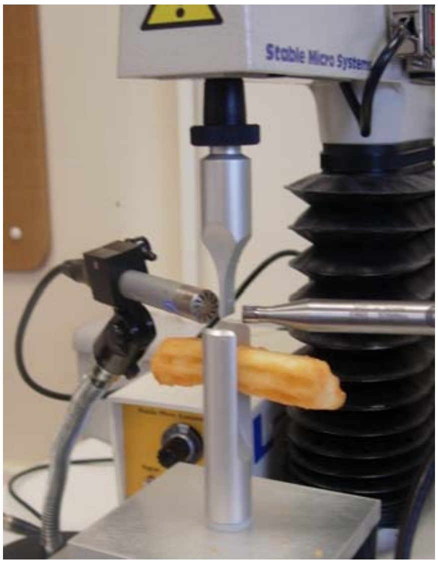


Figure 2. The experimental set-up of acoustic characterisation of crispy foods. The food sample was cut by a Volodkevich Bite Jaw probe and its acoustic releases were recorded by the two microphones.

Analysis of audible acoustic signal together with sensory panel test results indicated significant correlation between acoustic release and sensually perceived crispness of chips. Further analysis revealed possible differentiation between crispness and crunchiness based on acoustic nature: crunchy foods might produce a greater maximum SPL (Sound Pressure Level) or louder sound, whereas crisp foods were found to produce a greater number of sounds that are not so loud. Preliminary analysis of ultrasound signals also showed significant correlation to the sensory crispness. It was noticed that food which was sensually perceived crunchy did not produce as much ultrasound, whilst producing more low frequency sound, as compared to some crispy foods, despite being much louder.

It is clear that while mechanical tests work well for the crispness characterisation of low-moisture content foods, the passive acoustic method can give much better quantitative crispness description for those foods which have a soft interior. More over, a synchronised acoustic and mechanical assessment may provide a perfect solution for food texture characterisation of a wide range of food materials.

Sensory perception can not only be objectively quantified but also showed to have close correlation to oral behaviour, in particular to the activities of facial muscles. To confirm this, food stickiness together with food hardness have been chosen for investigation. Surface electromyography (sEMG) has been used to monitor the bursting activities of major facial muscles during mastication, e.g. temporalis, masseters, and the digastric (see Figure 3). It was observed that sticky food makes eating more difficult. In consuming such foods, facial muscles have to work much harder (both the bursting amplitude and the cumulated muscle work), accompanied often by some irregular jaw and tongue movements. Figure 4 shows the total muscle work used in the consumption of food gels against sensory test results, where the muscle work increases monotonously with the sensory food stickiness. Such a correlation between oral physiological behaviour and the sensory perception provides useful insight information of how food texture is possibly perceived and how food texture affects our eating behaviour.

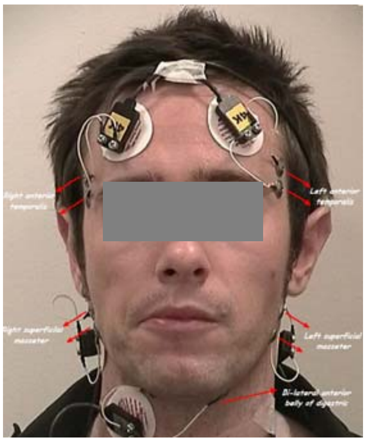


Figure 3. Experimental set up of surface electromyography, where electrodes were attached to target facial muscles to record their activities during an eating cycle.

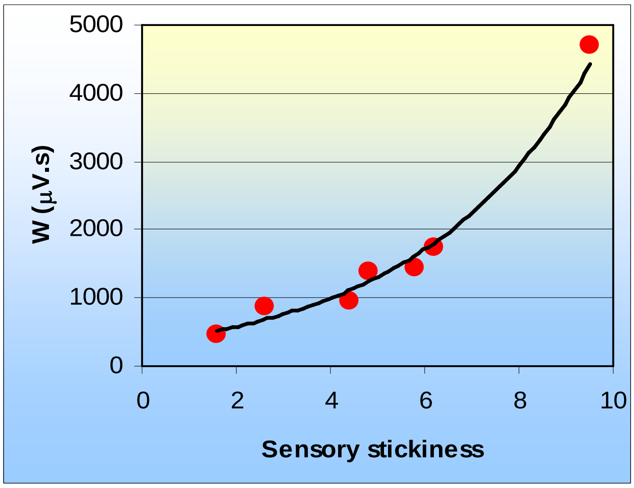


Figure 4. Correlation of the work done by the facial muscle and sensory perceived stickiness.

Results from our studies indicated that food sensory features can be objectively assessed. Food textural properties from instrumental assessments show very good correlation with those sensually perceived. Instrumental quantification of food texture has great advantages in terms of its reproducibility, accuracy, and more importantly cost-saving, compared to traditional taste panel methods.

References

1. Chen, J., Karlsson, C. & Povey, M. (2005). Acoustic envelope detector for crispness assessment of biscuits. *Journal of Texture Studies*, **36**, 139-156.

2. Varela, P., Chen, J., Fiszman, S. & Povey, M. J. W. (2007). Crispness assessment of roasted almonds by an integrated approach to texture description: texture, acoustic, sensory and structure. *Journal of Chemometrics*, **20**, 1-10.

Perceiving colour in natural scenes: constancy of colour categories

Kinjiro Amano[#], David H. Foster

School of Electrical and Electronic Engineering, University of Manchester, Manchester, UK
[#] k.amano@manchester.ac.uk

Introduction

Our ability to maintain an invariant perception of the colour of surfaces despite changes in the colour of the illumination is referred to as colour constancy. Many psychophysical experiments have been performed to measure this phenomenon, mainly with the technique of asymmetric colour matching, in which an observer adjusts the colour of a test field to match the colour of a reference field, under different illuminations, according to some criterion. Performance reaches intermediate to high levels in relation to an ideal match, although it depends on experimental conditions [1-3]. But there are theoretical difficulties with asymmetric colour matching, the most important of which is that it records only a relational judgement rather than an absolute one [4].

An alternative approach, which is much more direct than asymmetric colour matching, is colour naming. Typically, an observer assigns a colour name to a test surface using either an unlimited repertoire of terms or a prescribed finite set, such as the eleven basic colours terms [5-9]. Colour naming from a finite set has the advantage of being simple and intuitive to an observer, but it has the disadvantage that the terms of the set may not by sufficiently nuanced to capture the variety of colour appearance of surfaces in the natural environment. The problem is that a test surface chosen at random in a natural scene is unlikely to be described perfectly as, say, “green”, and it may need the addition of one or more modifiers to form combinations such as “light yellowish green” to achieve the required precision. Unfortunately, these modifiers are themselves open to uncertainty, with the result that any experimental variation with a change in illumination may be due either to a change in the interpretation of the name or to a change in the apparent colour.

It is, however, possible with computer-controlled rendering of natural scenes to vary the spectral reflectance of a test surface so that a particular colour term for a surface becomes optimal, and any shift of that term in colour space can be tracked as the illumination on the surface and scene changes.

In this study, categorical colour naming was performed with images of natural scenes simulated under separate daylights of correlated colour temperature 25000 K and 6500 K, corresponding to blue skylight and average daylight, respectively. By this method, colour constancy based on categorical naming seems to be as good as asymmetric colour matching.

Methods

Images of natural scenes were presented on a 20-inch CRT display (GDM-F520, Sony Corp., Japan) controlled by a graphics workstation (Fuel, Silicon Graphics Inc., CA) with spatial resolution 1600 × 1200 pixels, refresh rate approx. 60 Hz, and intensity resolution 10 bits on each RGB gun. The display system was regularly calibrated with a telespectroradiometer (SpectraColorimeter PR-650, Photo Research Inc., CA) to maintain adequate colorimetric accuracy; the errors in a coloured test patch on the display were in the CIE 1931 system < 0.005 in (x, y) and < 5 % in Y (< 10% at low light levels).

Four natural scenes, illustrated in Fig. 1, were selected from a hyperspectral database to allow the accurate control of illuminant and reflectance spectra [10]. The test surface was a sphere, covered with Munsell N7 paint, placed physically in the scene and whose surface colour was varied digitally. Images of the scenes were rendered under daylights of correlated colour temperature either 25000 K or of 6500 K. These illuminants were selected so as to be compatible with earlier studies in which a surface-colour judgement task was performed. The images on the screen subtended approx. 18° × 13° and the test target approx. 1° visual angle, at a viewing distance of 1 m.

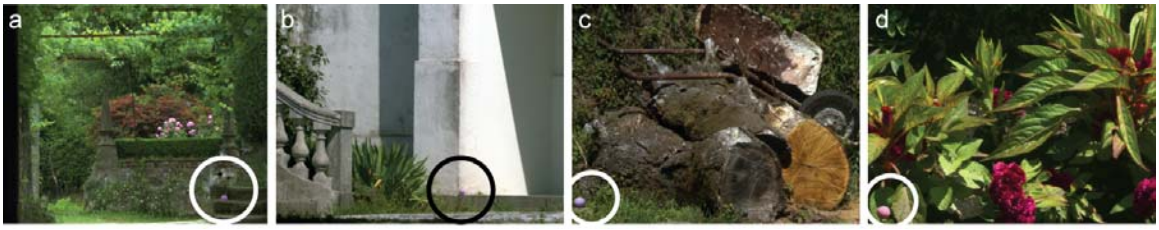


Figure 1. Four natural scenes used in the experiment. Each of the scenes, (a) garden, (b) house, (c) flowers, and (d) farm contained a test surface, a grey sphere, whose location is here indicated by a circle (not part of the stimulus image).

The surface reflectance of the test surface was manipulated so as to coincide with that of a sample drawn from approximately 430 Munsell reflectances [11], grouped into eight colour categories, namely, red, green, yellow, blue, pink, purple, brown, and orange [12]. Each category comprised approximately 60 samples depending on the display gamut. Only one category was tested in each experimental session.

In each trial, the observers viewed each image for 1 s and then named the colour of the test surface by pressing one of nine computer keys corresponding to the eight categorical colour terms plus neutral (equivalent to black, grey, or white). Each of the colour categories was tested in a different session with each of the four natural scenes. The order of categories and natural scenes was randomized over observers. Each observer performed approx. 900 trials per scene.

Observers

Twelve observers, 5 female and 7 male, aged 22–40 yr, took part in the experiment. All had normal colour vision and normal or corrected-to-normal visual acuity. Observers were free to move their eyes, and had unrestricted response time.

Results and Comment

For each scene, the colour-naming responses were pooled over observers for each scene, and grouped into three luminance levels so that each level consisted of approximately the same numbers of samples. At each luminance level, the distribution was smoothed by locally weighted polynomial regression, loess [13], in the CIE 1976 (u', v') chromaticity diagram. The estimated peaks of the distributions were taken as the foci of the colour categories, i.e. the focal colours.

For each of the colour categories, the positions of the focal colours shifted in the direction of the illuminant change, but the amount of the shift varied with the category. To quantify the effect of the illuminant change on categorical colour naming, a focal-colour constancy index was defined as follows. Let F_1 and C_1 be the positions of the focal colours and the closest Munsell colour under one illuminant, say 25000 K, and let F_2 and C_2 be positions under the other illuminant, say 6500 K. Then, a shift from F_2 by the offset between F_1 and C_1 defines a position F_2', that is, $F_2' = F_2 - (F_1 - C_1)$. Let a be the distance $F_2' - C_2$ and b be the distance $C_1 - C_2$. Then the focal colour constancy index (FCCI) is given by $1 - a/b$. As with the usual constancy index [3], perfect constancy corresponds to 1 and perfect inconstancy to 0. To obtain a robust estimate of the FCCI, the calculation was performed with the three closest Munsell colours.

Figure 2 shows the FCCIs for all the colour categories for each of the four scenes at the intermediate luminance level. The indices ranged between 0.7 and 0.9 in many of the categories, close to the typical values reported for colour constancy measured by other methods [1, 3, 10, 14], although the display colour gamut appeared to restrict responses with some luminance levels and some scenes and categories (indicated by *N* in Fig. 3). For some focal colours such as blue and purple, the FCCIs were almost invariant across luminance levels. There was little effect of different directions of illuminant change (not shown here).

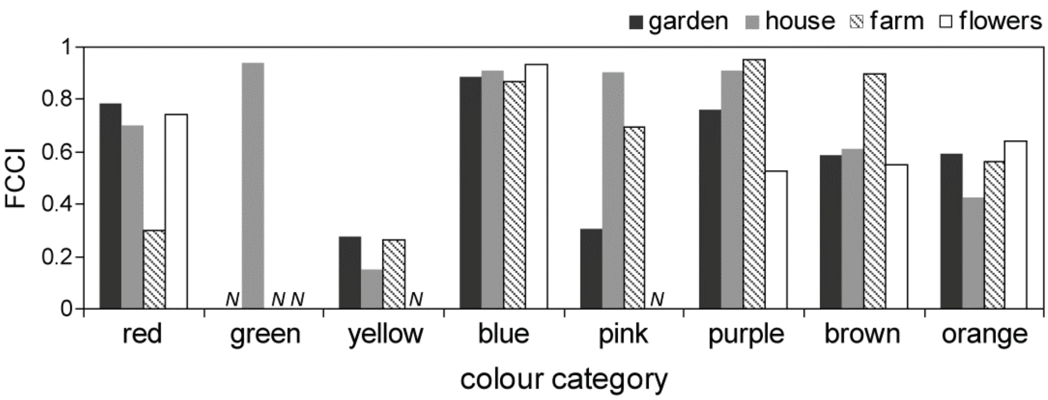


Figure 2. Focal-colour constancy indices for all colour categories in each scene. Omitted values are indicated by "*N*".

The present results suggest that absolute estimates of surface colour based on focal colours may be sufficiently robust and precise that they could anchor relative judgements of non-focal surface colours. The two types of judgements might therefore contribute in a complementary way to forming a reliable estimate of arbitrary surface colours in natural scenes.

Acknowledgements
This work was supported by the EPSRC (grant nos. EP/B000257/1 and EP/F023669/1).

References

1. D. H. Foster, K. Amano, and S. M. C. Nascimento, "Colour constancy from temporal cues: better matches with less variability under fast illuminant changes," Vision Research **41**, 285-293 (2001).

2. D. H. Brainard, W. A. Brunt, and J. M. Speigle, "Color constancy in the nearly natural image. 1. Asymmetric matches," Journal of the Optical Society of America A **14**, 2091-2110 (1997).
3. L. E. Arend, Jr, A. Reeves, J. Schirillo, and R. Goldstein, "Simultaneous color constancy: papers with diverse Munsell values," Journal of the Optical Society of America A **8**, 661-672 (1991).
4. D. H. Foster, "Does colour constancy exist?," Trends in Cognitive Sciences **7**, 439-443 (2003).
5. J. M. Troost and C. M. M. de Weert, "Naming versus matching in color constancy," Perception & Psychophysics **50**, 591-602 (1991).
6. T. Hansen, S. Walter, and K. Gegenfurtner, "Effects of spatial and temporal context on color categories and color constancy," Journal of Vision **7**, 1-15. (2007).
7. J. M. Speigle and D. H. Brainard, "Is color constancy task independent?," in *Recent Progress in Color Science*, (IS&T, 1997), 328-332.
8. R. M. Boynton and C. X. Olson, "Locating basic colors in the OSA space," Color Research and Application **12**, 94-105 (1987).
9. B. Berlin and P. Kay, *Basic Color Terms* (University of California Press, Berkeley, 1969).
10. D. H. Foster, K. Amano, and S. M. Nascimento, "Color constancy in natural scenes explained by global image statistics," Visual Neuroscience **23**, 341-349 (2006).
11. Munsell Color Corporation, *Munsell Book of Color-Glossy Finish Collection* (Munsell Color Corporation, Baltimore, MD, 1976).
12. J. Sturges and T. W. A. Whitfield, "Locating basic colours in the Munsell space," Color Research and Application **20**, 364-376 (1995).
13. W. S. Cleveland and S. J. Devlin, "Locally weighted regression: an approach to regression analysis by local fitting," Journal of the American Statistical Association **83**, 596-610 (1988).
14. D. H. Brainard, "Color constancy in the nearly natural image. 2. Achromatic loci," Journal of the Optical Society of America A **15**, 307-325 (1998).

Measurement with Persons: Concepts & Techniques as studied in MINET Repository and Think Tanks

Presenter: L R Pendrill,

SP Technical Research Institute of Sweden, Measurement Technology, Box 857, SE-50115 Borås (SE), phone:+46 767 88 54 44 leslie.pendrill@sp.se

Authors: B Berglund (MINET coordinator)[1], A Alfonsi[2], A Cancedda[2], F Crenna[3], J Drnovsek[4], R Emardson[5], G Gersak[4], G van der Heijden[6], A Höglund[1], K Kallinen[7], N Ravaja[7] and G. B. Rossi[3]

[1]*Stockholm University, Department of Psychology, SE-106 91 STOCKHOLM (SE) birgitta.berglund@ki.se*
[2]*Laboratory of Citizenship Science (LSC), Via Monte Zebio, 32 - 00195 ROME (IT)*
[3]*DIMEC, Dept. of Mechanics and Machine Design,Via all'Opera Pia 15A, University of Genoa, I - 16145 GENOVA, (IT)*
[4]*University of Ljubljana, Faculty of Electrical Engineering, Trzaska 25, 1000 LJUBLJANA (SLO)*
[5]*SP Technical Research Institute of Sweden, Measurement Technology, Box 857, SE-50115 BORÅS (SE)*
[6]*Wageningen UR, Biometris, PO Box 100, 6700AC WAGENINGEN (NL)*
[7]*Helsinki School of Economics, Centre for Knowledge and Innovation Research, Box 1210, FIN-00101 HELSINKI (FIN)*

Abstract

The European 'Measuring the Impossible' Network MINET promotes new research activities in measurement dependent on human perception and/or interpretation. This includes the perceived attributes of products and services, such as quality or desirability, and societal parameters such as security and well-being. The MINET consortium aims at consensus about how 'generic' metrological issues:

a) Measurement concepts & terminology
b) Measurement techniques
c) Measurement uncertainty
d) Decision-making & impact assessment

can be applied specifically to 'Measurement of Persons' in terms of 'Man as a Measurement Instrument' and 'Measuring Man'.

This presentation reviews the main achievements so far as achieved in MINET WP3, including in particular:
Think Tank events
On-line Internet Repository of current literature and Glossary

The four **Think Tanks** [1], dedicated to the four metrological issues a) – d) above, are open for participation and debate about measurement dependent on human perception and/or interpretation. Each Think Tank is intended, at least on a voluntary basis, to continue to work even beyond the official end of the MINET project.

The MINET on-line **Repository** [2] contains information about current literature; schools; approaches; and methodologies used in Measuring the Impossible activities and is freely available on the Internet. Several hundred references are made to major research work about measurement dependent on human perception and/or interpretation. The Repository has been accessed over 2000 times since its creation at the end of 2007. New references to the MINET Repository are sought publicly on a continuous basis, and you are welcome to submit your suggestions [2].

1 Measurement Concepts & Terminology

A **Glossary** of metrological terminology [3] is included in the MINET Repository, with an emphasis on the terms and concepts in measurement dependent on human perception and/or interpretation. The Glossary contents are ordered according the following categories:

- Entities, Quantities and Units
- Measurement
- Devices for Measurement
- Properties of Measuring Devices
- Measurement in Conformity Assessment

with about 60 fully-clickable terms – from Accidence, Calibration to Validity and Verification – and with many references to the International Vocabulary of Metrology [4] and other sources of terminology, including some definitions formulated in the MINET project.

The **MINET Think Tank A** is dedicated to the topic of Measurement Concepts & Terminology and held its inaugural meeting in Berlin (DE) 13th April 2007. The event debated the question:
"*Is different formulation of concepts & terminology in the different MtI fields hindering this development and how can we improve the situation?*"

The MINET Think Tank event A included an Introductory educational lecture: **"Crossdisciplinary terminology for properties of systems"** (Dr R Dybkaer, Frederiksberg Hospital, DK). Dr Dybkaer recalled the divisions of "property" by mathematical characteristics – different 'scales', progressing from the most basic, nominal and ordinal, to the 'rational' scales. This division in scale had been developed after the second world war in response to the need to extend measurement into the social and behavioural sciences [5].

Breakout discussions dealt with questions:
(I) What are the necessary basic concepts and terminology?
(II) Are there different concepts & terminology in the various fields?
(III) Is it important to harmonise?
(IV) How can we encourage harmonisation and/or innovation?
Apart from stimulating subsequent work on the MINET Glossary, these discussions concluded that it was particularly important to consider how to encourage harmonisation [question (IV)] in order to increase awareness/appreciation for the differences between the various MtI fields and the difficulties in understanding these differences as well as foster openness and respect.

2 Measurement Systems & Techniques

A second MINET Think Tank addresses Measurement Systems & Techniques in the various Measuring the Impossible fields and held an event at Portoroz (SLO) 27th September 2007. The event debated the question:

"What are the limitations of different measurement systems and techniques and can there be synergies between them?"

The MINET Think Tank event B included an Introductory educational lecture: "**Measurement Techniques in Communication and Media Psychology**" (Prof. Gary Bente, University of Cologne DE).

Breakout discussions mainly focused on the scope of measurement in terms of the following questions:

- Generalizability of results and limits of different techniques
- Can different techniques be combined?
- Examples of research questions that would benefit from a multi- or interdisciplinary approach

Subsequent work of the Think Tank B has included populating the MINET On-line Repository with references to current literature about Measurement Systems & Techniques.

3 Measurement Uncertainty

A third MINET Think Tank C aims to tackle the subject of Uncertainty in measurement dependent on human perception and/or interpretation and organised an event in Rome (IT) 9 - 10th October 2008 under the title:

"How is measurement uncertainty evaluated in the different Measuring the Impossible fields?"

The MINET Think Tank event C included Introductory educational lectures: "*Uncertainty Sources*", Prof G B Rossi, University of Genoa (IT) and *"Uncertain Measures? Comparison between Causal and Systemic Sciences from Viewpoint of an Applied Methodologist"* Prof L Cannavò, University "La Sapienza", Rome (IT)

This was followed by **Breakout discussions** considering the following questions:

(I) *Evaluation: Typology of uncertainty sources?*
(II) *Concepts: Relation uncertainty ⇔ liability & validity?*
(III) *Evaluation: Unknown laws – how to calculate U?*
(IV) *Evaluation: Alternative, non-numerical estimates of U?*

In debating **concepts**, specifically (II) the relation between uncertainty and validity, the MINET Think Tank C observed that researchers from the various MtI fields had more similarities than differences in their interpretation of these terms. This has stimulated subsequent work on the MINET Glossary, including consideration of terms such as Validity.

The **evaluation of measurement uncertainty** (III) when underlying laws are unknown, as is often the case in measurement dependent on human perception and/or interpretation, was considered to be a relatively difficult task. One has to deal often with multidimensional and correlated measurements demanding different techniques such as bootstrapping, as well as playing with data and exploiting familiarity. There is also uncertainty in measurement models as well as measurement uncertainty.

4 Decision-making & Impact Assessment

A final MINET Think Tank D event took place at Wageningen (NL), 13th May 2009 under the title: "Decision-making & Impact Assessment" and debating the questions:

(I) *"How can decisions be made based on Perceptual Measurements?"*
(II) *"What are the impacts?"*

The event included breakout discussions amongst the participants, debating these questions. Uncertainty is important in decision-making but estimation of uncertainty in perceptual measurements is relatively difficult. For instance, there is no ground truth in e.g., beauty compared to e.g., speed. It is important to decide when not to decide, e.g. when measurements are certain enough.

The MINET Think Tank D event also had introductory and case study lectures:
"*Science versus Justice: the case of Lucia de B*", Prof Richard Gill, Mathematical Institute, Leiden University (NL)
"*Probabilistic health impact assessment for decisions on food safety*", Hilko van der Voet, Wageningen UR (NL)

Conclusions & future work

The unique mix in the EU network MINET [6] of physicists, metrologists, medical scientists, neurologists, and scientists from psychology and sociology is reaching consensus on fundamental aspects of metrology in the field of human perception and/or interpretation as measurement. One has found that different disciplines have used different terminology for basically the same metrological aspect, such as measurement uncertainty. Now new research constellations and project proposals are being formulated for the future in this new area of metrology.

Acknowledgments

Funding for the MINET Network is generously provided until 2010 as part of the EU 6th Framework Programme as a NEST Pathfinder project Contract No 043297.

Professor Birgitta Berglund and her colleagues at Stockholm University, Department of Psychology have coordinated the MINET project.

References

1. MINET Think Tanks http://lesliependrill.wordpress.com/minet-wp3-think-tanks/
2. MINET Respository http://minet3repository.wordpress.com/
3. MINET Glossary http://minet3repository.wordpress.com/measurement-domains/measurement-concepts-terminology/minet-glossary-of-perceptive-metrology/
4. VIM 2008 International vocabulary of metrology - Basic and general concepts and associated terms (VIM), Joint Committee on Guides in Metrology (JCGM) http://www.bipm.org/en/publications/guides/vim.html
5. Stevens, S.S. 1946 "On the Theory of Scales of Measurements", *Science*, **103**, 677-680
6. MINET www.measuringimpossible.net

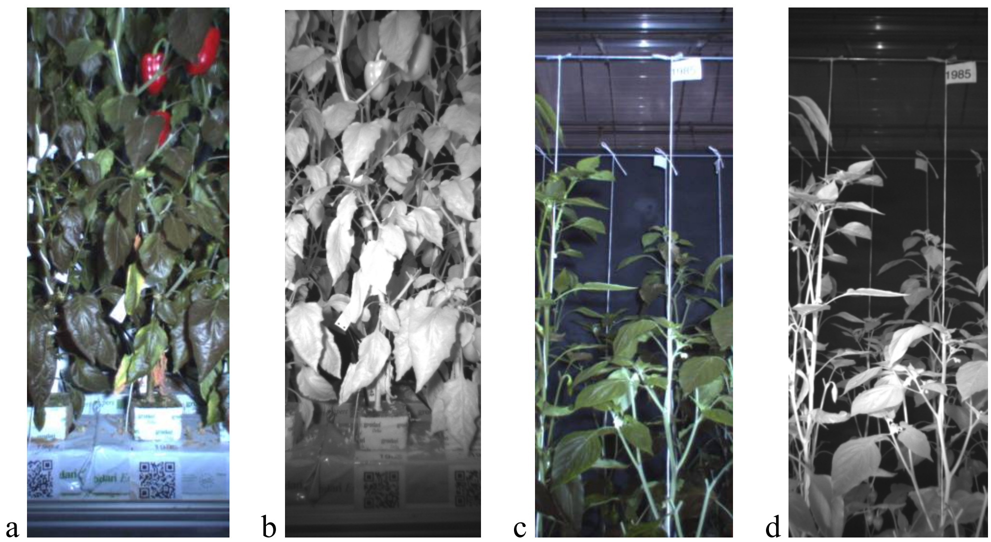
Spy-See - Advanced vision system for phenotyping in greenhouses

G. Polder[1], G.W.A.M. Van Der Heijden[1], C.A. Glasbey[2], Y. Song[2] and J.A. Dieleman[3].

[1]Wageningen UR, Biometris, P.O. Box 100, 6700 AC, Wageningen, Netherlands, [2]Biomathematics & Statistics Scotland, JCMB, The Kings buildings, Edinburgh EH9 3JZ, Scotland, United Kingdom, [3]Wageningen UR, Plant Research International, P.O. Box 16, 6700 AA, Wageningen, Netherlands. Email main author: gerrit.polder@wur.nl

Introduction

The EU project SPICY (Smart tools for Prediction and Improvement of Crop Yield) aims to develop a suite of tools for molecular breeding of crop plants for sustainable and competitive agriculture. The tools help the breeder in predicting phenotypic response of genotypes for complex traits under a range of environmental conditions. Pepper will be used as a model crop.
Molecular breeding will not completely replace large scale phenotyping. Traditionally phenotyping involves human interpretation of a large number of features related to complex characteristics of plants. These measurements take a lot of time and sometimes also are hampered by different perception and/or interpretation for different observers.
Hence, automated and fast high-throughput tools to reduce the amount of manual labour necessary in phenotyping experiments are called for. In the SPICY project an image analysis tool will be developed to measure large numbers of phenotypic traits automatically. This abstract will describe the technical details of the vision system we designed (Spy-See).



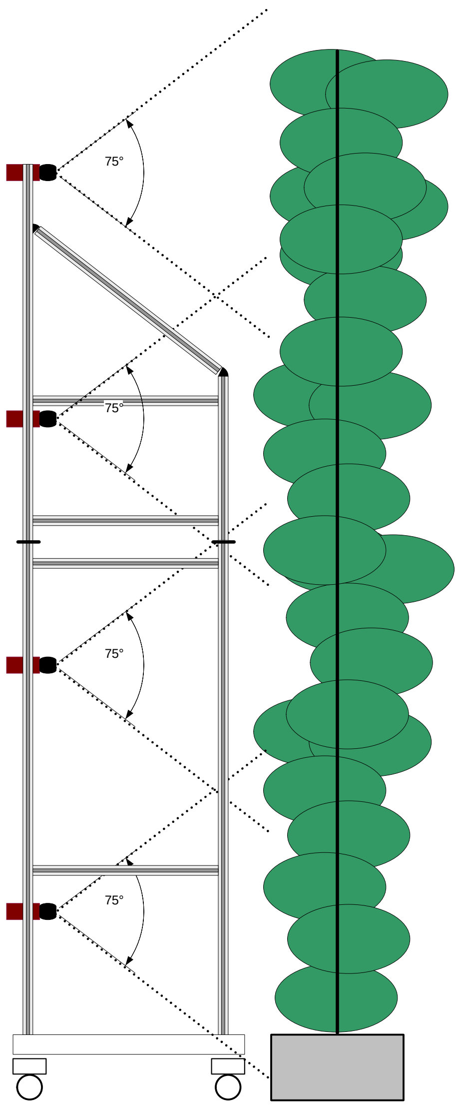
RGB images ((a) and (c)) and infrared images ((b) and (d)) of pepper plants in the greenhouse. Images (a) and (b) show the lower quarter, whereas (c) and (d) show the upper quarter. In total 4 cameras per type at a height difference of 75 cm will record the fully grown plants.

System design

Important features for phenotyping pepper plants include number and size of leaves, flowers and fruits, time of flowering, and color of leaves and fruits. The human observer perceives the information in a three dimensional (3D) scene. Therefore it is important that the imaging system also produces 3D images, in order to relate the measurements to human perception.

The plants grow in rows with a row distance of 1 m. In between are heating pipes. The maximum height of the plants is about 3 m. We designed a system on a trolley which can travel over the heating pipes. The distance to the plants is very short, therefore to cover the whole 3 m height we use high resolution cameras with a very large field of view lens at four height positions. Three different cameras are used:

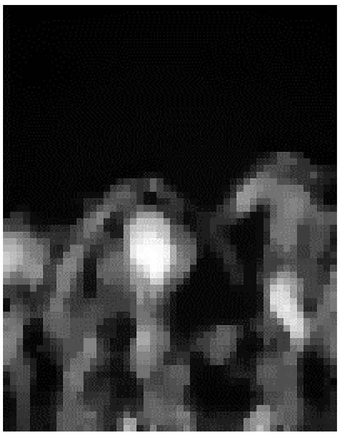
1. high resolution color cameras
2. high resolution infra red cameras (750-900 nm)
3. low resolution range cameras, based on the TOF (Time of Flight) Principle



Side view drawing and photo of the trolley

Close-up of color and infrared camera and strobe

For illumination xenon strobed flashlights are used. For image capture all cameras and flashlights are triggered simultaneously using an encoder on one of the wheels of the trolley. In this way images are captured automatically at a fixed interval when the trolley moves over the heating pipes. The very short duration of the strobe and camera shutter (~50 µs) eliminates disturbing light sources as direct sunlight and assimilation light. By capturing a large number of overlapping images, and with the low resolution information from the range cameras we expect to be able to do high resolution 3D reconstruction.

a  b 

Intensity (a) and depth (b) image of pepper plants produced by the TOF range camera. In image (b) the distance scale is 80 cm (black) to 150 cm (white).

Conclusion

The Spy-See vision system described here functions very well and produces a huge amount of detailed image information. This image information together with manual measurements will be used as input for the image analysis tool that will be developed in the SPICY project.

Designing Environments for the Elderly: Measuring and Tracing the Shifts in Emotional Responses

Alessio Corso*, Hilary Dalke, Laura Stott, Uta Krieger

Kingston University, Design Research Centre, United Kingdom

*Corresponding author: a.corso@kingston.ac.uk

Abstract

The results of a fifteen month research project conducted by the Design Research Centre (DRC) at Kingston University aimed to inform the design of environments for males. The investigation focused on aspects of sensory design, namely colour and fragrance.

The outcomes of the project were incorporated into the refurbishment of an activity room at an Age Concern Centre in New Malden. The aim of the refurbishment was to create an environment that is welcoming, enticing, calming and relaxing through the use of colour and fragrance design interventions. The activity room was underused; few males made use of the organisation's activity room facilities and the management staff was keen to encourage use of the room by men. These factors made the activity room an ideal location for the testing of the results for this project.

It was agreed that the refurbishment would incorporate findings from previous colour and fragrance testing (Dalke H. et al., 2008) carried out in the DRC on a research project funded by the Arts and Humanities Research Council (AHRC). The most liked fragrance from this testing was identified as Fragrance 'C'; one of eight fragrances donated by project collaborators Givaudan. This fragrance was proven to be associated mostly with pink / purple and also green colour hues.

Previous research (Dalke & Stott, 2006), and also research by other authors in the realm of multi-sensory design, indicated that colour and fragrance interventions must work harmoniously (congruently) in order to help create an environment that would have a beneficial effect; testing this hypothesis with day centre visitors at Age Concern was conducted between March and May 2009 .

The colours chosen for the activity room originated from colour palettes associated with Fragrance 'C'. The potential 'match' between the fragrance and the colours was believed to increase the chance of creating a congruent environment. The method used to evaluate this work comprised of the Lanius & Russell 1984 Model of Affective Appraisal of Environments (Russell, J. A., & Lanius, U. F., 1984). People's emotional responses were documented in four stages throughout this refurbishment process:

Stages:

1. Before the refurbishment, no fragrance
2. Before the refurbishment, with fragrance
3. After the refurbishment, no fragrance
4. After the refurbishment, with fragrance

This short paper summarises the initial results obtained from the project and documents how people's emotional feelings towards the activity room environment at Age Concern changed, were measured and mapped throughout the four stages of the environmental design process.

Could the environment be changed to increase usage of the room and entice more male service users? Would the measurement of people's emotional responses show any shift as the design interventions were introduced? The results showed a conclusive move in people's emotional responses to the environment.

Key Words
Measurement, Colour, Emotional Responses, Environments, Multi-sensory Design, Congruency, Environments for Males, Fragrance.

The project was funded by the Arts & Humanities Research Council (AHRC).

Project collaborators
Anne Bren (Operations Manager), Carol Marley (Day Centre Manager); Age Concern, Kingston-upon-Thames.
John Behan (Research Director), Anne Churchill (Development Manager); Givaudan, Ashford

References

Dalke, H., & Stott, L. J. (2006). Colour Acceptability III: Colour/Fragrance Congruency and Real Room Test. Industrial Research Funded by the Strategic Research Fund of ICI PLC. Kingston University.
Dalke, H., Stott, L. J., Corso, A., Jehoel, S., & Spence, C. (2009). Multisensory Design Interventions in Perception of Environments. Industrial Research Funded by the Arts and Humanities Research Council. Kingston University.
Russell, J. A., & Lanius, U. F. (1984). Adaptation level and the affective appraisal of environments. *Journal of Environmental Psychology, 4*, 119-135.

An explorative study of materials' perceptive and associative properties

Caroline Cederström, Siv Lindberg, Mikael Lindström

Innventia
caroline.cederstrom@innventia.com

INTRODUCTION: Materials science is the study of measurable technical properties of materials and its application to science and engineering. However materials also have non-technical properties; for example, wood is considered natural, warm, associated with characteristic sounds and smells, ages nicely and carries associations of craftsmanship; metals appear cold, precise, and sterile; gold conveys values of wealth. Ashby (2004) argues that a material can have a personality when it is used in a product. and just like an actor it can assume many personalities. However he further states that there is a character hidden in a material even before it has been made into a recognizable form – "a sort of embedded shy one, not always obvious, easily concealed or disguised, but one that when appropriately manipulated conveys its qualities into the design". There is research on non-technical properties of material; however this has been studied with the material embedded in a product (Chang, 2008; Karana, 2006; Kesteren, 2005). The present study follows up on Ashby statement that there is a character hidden in a material, and aims at understanding the underlying characteristics in terms of associations and perception of materials, independent of product or context. More specifically the purpose of this study is:

1. To identify what types of non-technical descriptors are used to describe materials
2. To establish if materials differ in terms of non-technical properties, if so which ones.
3. To establish any perceptive and associative dimensions of materials.

METHOD: *Part one*- In order to obtain non-technical associative and perceptual descriptors for materials, a focus group discussion was conducted with three participants who worked with materials (two architects and a designer). Firstly the participants discuss how materials can convey feelings, thoughts, moods and memories. Secondly a set of materials were presented on a table and the participants were asked to group them into materials they liked, and materials they didn't like (from the modulator material sample box, www.modulor.de) and explain why. After the focus group interview the participants were asked to list non-technical descriptors for materials. The focus-group interview was taped and all the non-technical descriptors of materials were extracted, and along with the lists of non-technical descriptors written down, these words provided the basis for the questionnaire.
Part two – An expert panel of twelve art students from the masters program at University College of Arts Crafts and Design, Stockholm were asked to look at and feel 37 material samples from the modulor sample box which were displayed with a number, as well as some material samples from Sandvik, a materials technology company. The participants were then to indicate which five out of 101 non-technical material descriptors from the questionnaire they would use to describe each material. The participants filled out the questionnaire at the same time, but were asked not to discuss the task.

RESULTS: 1. To identify what types of non-technical descriptors are used to describe materials 101 descriptors were obtained from the focus group discussion. These were then organized into 14 themes depending what they pertained to. The groups were *aesthetics* (e.g. beautiful, ugly, beautifully-ugly, beautifully-disgusting); *authenticity* (e.g. fake, genuine, artificial); *time* (e.g. historical, classical, dated, retro, futuristic, contemporary, ages nicely, does not age nicely); *technology* (e.g. high tech, low tech, advanced, high performance); *comfort* (e.g. cosy, comfortable, uncomfortable, cuddly, makes me shiver); *hygiene* (e.g. disgusting, dirty, fresh, unwashed, toxic); *style* (cheap, expensive, porn-like, kitsch-like, elegant, sexy); *nationality* (e.g. Italian, Japanese, German); *expectation* (e.g. predictable, familiar, surprising, unexpected, weird, obvious; *practicality* (e.g. practical, unpractical, useful, solid); *intriguing* (e.g. interesting, inspiring, exciting, indifferent, pointless, provocative); *humour* (e.g. funny, boring, humorous, corny, ironic), *naturalness* (e.g. rustic, natural, homespun, recycled, eco-friendly, raw); *mood* (nice, warm, friendly, aggressive, harmonious).

2. To establish if materials differ in terms of non-technical properties the materials were collapsed into seven groups, namely plastic, rubber, composite, wood, paper, metal and textile A single classification ANOVA found that material groups could be differentiated between on fifteen of the descriptors, namely, *ages nicely* ($F_{(6, 19)} = 4.7$, $p < 0.05$, $\eta^2 = 0.17$), *cuddly* ($F_{(6, 19)} = 2.74$, $p < 0.05$, $\eta^2 = 0.4$), *disgustingly beautiful* ($F_{(6, 19)} = 2.92$, $p < 0.05$, $\eta^2 = 0.15$), *eco-friendly* ($F_{(6, 19)} = 2.79$, $p < 0.05$, $\eta^2 = 0.63$), *elegant* ($F_{(6, 19)} = 2.71$, $p < 0.05$, $\eta^2 = 0.75$), *friendly* ($F_{(6, 19)} = 2.71$, $p < 0.05$, $\eta^2 = 0.75$), *futuristic* ($F_{(6, 19)} = 2.88$, $p < 0.05$, $\eta^2 = 0.4$), *harmonious* ($F_{(6, 19)} = 2.65$, $p < 0.05$, $\eta^2 = 0.19$), *real* ($F_{(6, 19)} = 2.7$, $p < 0.05$, $\eta^2 = 0.66$), *makes me shiver* ($F_{(6, 19)} = 3.42$, $p < 0.05$, $\eta^2 = 0.35$), *solid* ($F_{(6, 19)} = 2.89$, $p < 0.05$, $\eta^2 = 1.29$), *toxic* ($F_{(6, 19)} = 4.63$, $p < 0.05$, $\eta^2 = 0.81$), *unwashed* ($F_{(6, 19)} = 3.22$, $p < 0.05$, $\eta^2 = 0.13$), *useful* ($F_{(6, 19)} = 3.16$, $p < 0.05$, $\eta^2 = 0.94$), *warm* ($F_{(6, 19)} = 5.9$, $p < 0.05$, $\eta^2 = 1.25$). No post-hoc analysis were conducted in order to investigate which materials differed on which descriptors, as this would have resulted in 105 post-hoc comparisons, and was not addressing the hypothesis. Mean frequencies and standard deviations are presented in

Table 1. Mean frequency and (standard deviation) for each material and descriptor. Empty slots represent a frequency of zero

	plastic	rubber	composite	wood	metal	textile	paper
ages nicely				0.67 (0.58)	0.60 (0.55)	1.33 (0.58)	0.25 (0.50)
cuddly	0.20 (0.45)	1.33 (1.53)			0.20 (0.45)	1.33 (0.58)	0.25 (0.50)
disgustingly beautiful					0.80 (0.84)		
eco-friendly				2.00 (1.73)	0.40 (0.55)	1.00 (1.00)	0.75 (0.96)
elegant	0.40 (0.55)	0.33 (0.58)	0.67 (0.58)		1.80 (1.30)		1.50 (1.29)
friendly	0.80 (0.84)	2.00 (1.73)			0.20 (0.45)		1.75 (0.96)
futuristic	0.20 (0.45)	0.33 (0.58)	1.33 (1.15)		1.20 (0.84)	0.33 (0.58)	
harmonious	0.20 (0.45)				0.20 (0.45)		1.00 (0.82)
real	0.40 (0.55)		0.33 (0.58)	1.67 (0.58)	1.60 (1.34)		0.75 (0.96)
makes me shiver		1.67 (1.53)	0.33 (0.58)	0.33 (0.58)		0.67 (0.58)	
solid	0.60 (0.89)		2.67 (1.53)	1.00 (1.00)	2.00 (1.87)	0.33 (0.58)	
toxic	1.80 (1.64)	3.00 (1.00)		0.33 (0.58)	0.60 (0.55)	1.00 (0.00)	0.25 (0.50)
unwashed	0.40 (0.55)	1.00 (0.00)	0.33 (0.58)			0.33 (0.58)	

useful	0.80 (0.45)		1.33 (1.53)	3.00 (2.00)	0.60 (0.89)	0.33 (0.58)	0.50 (0.58)
warm	0.20 (0.45)	1.67 (1.53)		1.00 (0.00)	0.20 (0.45)	4.33 (2.89)	1.25 (0.50)

3. To establish any perceptive and associative dimensions of materials.

A principle components analysis (PCA) was performed in order to identify and compute underlying dimensions of perceptive and associative properties of materials on a co-occurrence matrix. The initial eigen values showed that the first factor explained 34% of the variance, the second factor 19% and the third factor 15% of the variance, the fourth to seventh factor had a eigen value under 1 and were not used in accordance with the Kaiser criterion. A factor analysis PCA was done on the mean frequencies a descriptor had been used per material group, with the three factors explaining 68% of the variance. A varimax rotation provided the best defined factor structure. The factor names were obtained by analyzing which descriptors had the highest frequencies in the materials that loaded highest in each factor. The first category correlates with descriptors as nice, tactile, warm, eco-friendly, and natural; this factor is interpreted as *earthy.* The second factor correlated with descriptors such as advanced, futuristic, high-tech, real, simple and solid; this factor is interpreted as *reliable.* The third category correlates with descriptors as aggressive, contemporary, exciting, funny, interesting, kitsch and tactile; this factor is interpreted as *stimulating.* The factor loading matrix of this final solution is presented in table 2.

Table 2. Factor loadings and communalities based on 101 material descriptors with varimax rotation. Factor loadings > 0.65 are in bold

	earthy	reliable	stimulating	communalities (multiple R^2)
plastic	0.55	0.31	0.34	0.28
rubber	0.03	0.03	**0.95**	0.08
composite	0.16	**0.85**	-0.02	0.37
wood	**0.69**	0.45	-0.13	0.39
paper	**0.72**		0.17	0.21
metal	-0.07	**0.83**	0.11	0.30
textile	**0.77**	-0.11	-0.10	0.21
Expl.Var	1,92	1,73	1,09	
Prp.Totl	0.27	0.25	0.16	

CONCLUSION/DISCUSSION: The focus group part obtained 101 descriptors used to describe non-technical properties of materials which were grouped into fourteen themes. Out of the 101 original descriptors, fifteen could be used to differentiate between material groups. Although these findings are due to the frequency of descriptors being significantly different to zero, it still shows that the descriptors differentiated between materials in the sense that these descriptors were only applicable to certain materials. Overall, the factor analysis based on the obtained descriptors indicated three distinct factors underlying materials' perceptions and associations; these were interpreted as *earthy, reliable* and *stimulating*. The results of this study suggest that materials can be differentiated between both in terms of non-technical descriptors as well as non-technical dimensions. The collapsing of materials was done in accordance with the way the samples were divided in the accompanying guide; however they could have been grouped differently, for example, plastics and rubbers could have been into a polymers group, and cork and leather could have been grouped into a natural materials group. Both the choice of materials and grouping of materials affect the results and must be considered when interpreting the results. Further studies will consider the validity and reliability of this analysis, by using a wider range of materials, participants and other statistical methods. As a first study of materials' identity independent of context, these results may shed some light on the innate characteristics of materials, which can be useful as a starting point for further research on materials non-technical characteristics.

Investigating the Acoustic Properties of Materials with Tuning Forks

Wongsriruksa, S.[1], Laughlin, Z.[1], Naumann, F. [1], Conreen, M.[2], and Miodownik, M.A.[1]

[1] *Materials Research Group, Engineering Division, King's College London.*
[2] *Design Department, Goldsmiths College, London.*

Background

Acoustic properties of materials are not often taken into consideration during material selection due to a lack of data. From a purely physical perspective, two principle factors influence the sound of a tuning fork: the shape of the fork, and the material from which the fork is made. These factors affect both the pitch of the note (frequency of sound), and its quality. The pitch emitted when a tuning fork is struck relates to two material properties: elastic modulus, and density of the material. The pitch of a tuning fork can be expressed through a simple equation:

$$f \propto \frac{1}{l^2}\sqrt{\frac{AE}{\rho}} \tag{1}$$

where f is the frequency of the fork, A is the cross-sectional area of the tuning fork, l is the length of the fork's tines, E is the elastic modulus of the material, and ρ is the density of the material [1]. As equation (1) demonstrates, an increase in the length, l, of the fork tines increases the amount of a material that needs to oscillate in order to produce the sound wave. As a result, the tines move more slowly, with each oscillation compressing the air over a greater period of time, generating waves of lower frequency. This lower frequency is heard as a tone of a lower pitch, or in other words, a deeper note is produced. Therefore, a standard set of tuning forks produce a scale of notes by offering a range of sizes, where the shorter forks produce the higher frequency notes and the longer forks make the lower frequency notes. In order to fine tune the tone of an individual fork to the desired note, material is removed from either the ends of the tines in order to shorten them by a tiny amount, or from the base of the forks to fractionally lengthen them. Equation (1) also shows that changing the density or elastic modulus of the tuning fork material, will also change the pitch of the note produced. This is the origin of the characteristic sound of a material.

Acoustic brightness is another acoustic property of materials which defines how much a material damps vibrations. Bright materials, like brass, emit sounds for a long time, while the reverse is true of dull materials, like acrylic, which absorb sound strongly. The property is typically quantified experimentally by measuring a material's coefficient of loss, which is a measure of how strongly vibrations are absorbed by a material.

Ashby and Johnson have combined acoustic pitch and acoustic brightness into a materials selections tool for acoustic properties by plotting the theoretical relationship between the acoustic pitch and the acoustic brightness of a wide range of materials in their multidimensional scaling (MDS) map of acoustic properties [2]. The map shows the distribution of different types of materials in relation to their acoustic properties: materials close together on the map are predicted to behave similarly acoustically even if they are from a different family material such as metals, ceramics, natural materials and polymers. It is interesting to note that according to this MDS, the pitch of steel is within the range attributed to obeche wood, the materials being differentiated simply by the difference in acoustic brightness.

In this work, we use tuning forks as a way to closer examine the acoustic properties of materials. This approach has never been experimentally used in a systematic way, neither from a physical perspective nor from an experiential perspective of human acoustic perception. To carry out such an analysis has been the aim of the investigation reported in this paper. To this end we created a set of tuning forks that keep form constant and employ materiality as the variable, enabling the exploration of the effect of different materials on acoustic pitch and acoustic brightness. Our aim was to establish, firstly whether our experimentally measured MDS diagram matches that predicted by Ashby and Johnson; and secondly to investigate whether musicians perception of the quality and pitch of the sound of the tuning forks matched classifications predicted by theory and measured by experiment.

Methods

Tuning forks were made in identical dimensions from the following materials; stainless steel, mild steel, gold plated steel, brass, copper, zinc, lead, lead-tin solder, walnut, spruce, obeche, plywood, bass, ironwood, tufnol, nylon, and acrylic.

In order to obtain consistent repeatable data the following experimental set up was created. A wooden vice was secured to a laboratory bench top and used to hold the tuning fork tightly in place. A microphone that rested upon a foam base was mounted 1 cm from tines, in a stand at 90° to the face of the fork. The output of the microphone was connected directly to the sound card of a computer. Each fork was played by pinching the tines together with forefinger and thumb then releasing them simultaneously. MATLAB, the interactive environment for algorithm development, data visualization, data analysis, and numeric computation [3], was used to digitally record and analyse the data. The standard MATLAB function, 'wavrecord' was used to interface the acoustic signal and a combination of MATLAB and custom tools were used for signal processing, further analysis of the input, to generate amplitude versus time plots, and to generate power spectra. The resonant frequency of each tuning fork was measured by extracting the peak to peak time interval of the wave function. An exponential decay was used as a simple way of quantifying the loss factor, namely the time constant of the decay, τ in which the acoustic brightness of each fork was calculated by this factor.

Results

Figure 1 shows some of the results of the quantitative analysis. It is a plot of acoustic brightness (K) versus acoustic frequency (f) or pitch. It shows a range of two orders of magnitude between the brightest metal (gold plated steel) and the dullest wood (bass). However, it can be seen that some of woods have a pitch that is higher than that of the metals, for instance walnut is higher than brass and copper. Some of the metals such zinc, lead, and lead-tin solder were so dull that they cannot be recorded in a reproducible accurate signal and are at present excluded from the plot. Other results on the effect of age and temperature on acoustic properties have also been measured.

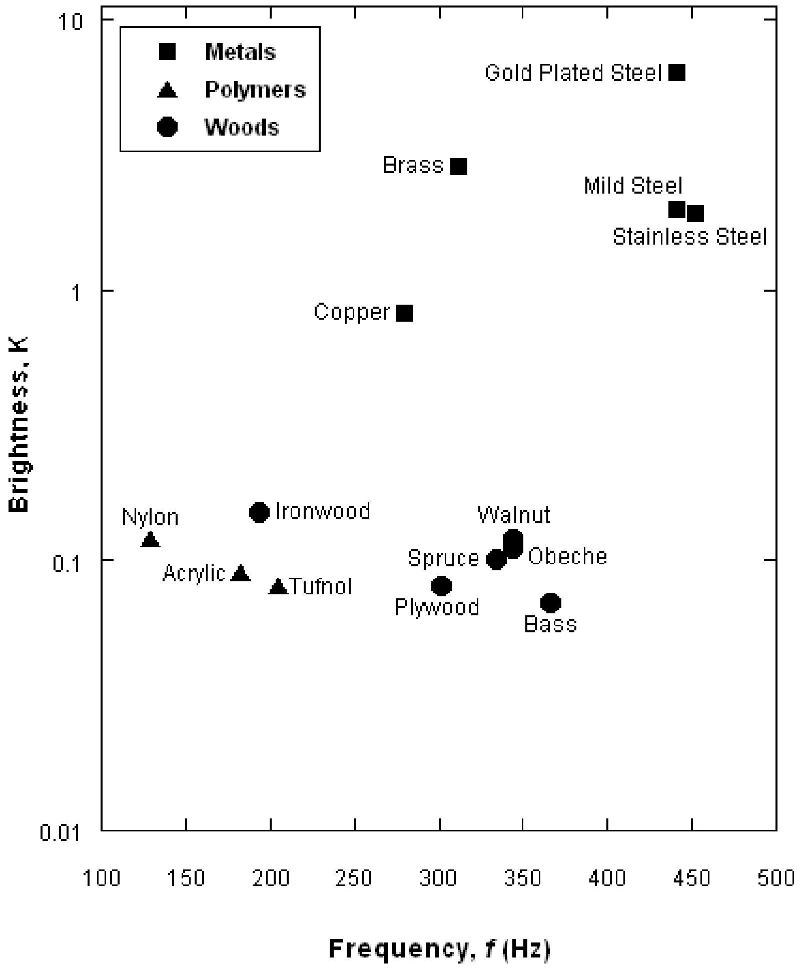


Fig. 1 The relationship between acoustic brightness and acoustic frequency measured for a range of tuning forks of identical dimensions made from different materials.

References

[1] D.T. Burleigh and P.A. Fuierer. *Tuning Forks for Vibrant Teaching*, JOM, Vol.57, No.11, pp.26-27, 2005.

[2] M. Ashby and K. Johnson, *Materials and Design; The Art and Science of Material Selection in Product Design*. Elsevier, 2002.

[3] MATLAB, MathsWorks – http://www.mathworks.com/, 2008

The Taste of Materials: Spoons

Laughlin, Z.[1], Conreen, M.[2], Witchel, H.[3] and Miodownik, M. A.[1]

[1] *Materials Research Group, Engineering Division, King's College London.*
[2] *Design Department, Goldsmiths, University of London.*
[3] *Brighton and Sussex Medical School, University of Sussex.*

Background

Tastes are received through our taste buds, which are located in adults on the upper surface of the tongue. There are five basic tastes: bitter, salty, sour, sweet, and umami, although 'fat' is also now becoming a candidate for distinct taste sensation. These formal tastes are not the only component of the sensations associated with the mouth and the experience of tasting [1]. Other important factors include smell, detected by the olfactory system, texture detected by mechanoreceptors, and temperature, detected by thermoreceptors. The chemical aspects of the taste of inedible materials, such as those being considered in this study, are often discussed in terms of their reduction potential, in other words their susceptibility to being oxidized in the mouth [2- 4]. These potentials have been measured for most materials, and confirm broad trends of taste: metals that are highly susceptible to oxidization such as copper and aluminium have a noticeable 'metallic' taste, whereas gold and silver are almost tasteless (hence the high status of silverware cutlery). In this study we have carried out a set of experiments to test the correlation between the perceived taste of materials and their measurable physical and electrical properties.

Method

Fifty volunteers were recruited to take part in a set of taste tests. To be accepted as participant in the study the volunteers had to be between 18 and 65 years of age, in good general health and not pregnant. In addition, they could not be suffering from a cold or influenza at the time of the test, or suffering from any general medical condition known to compromises the sense of taste and smell, specifically synaesthesia (taste based), any disorders of olfaction (anosmia, hyperosmia, hyposmia, dysosmia) and any disorders of taste (ageusia, dysgeusia, etc.)

Six identical stainless steel teaspoons were electro-plated with the following pure metals: gold, silver, copper, tin, chrome, and zinc. Each metal was selected because of its non-toxic status and suitability for contact with human skin and mucus membranes.

For each volunteer eight teaspoons (six of varying materials and two non-plated stainless steel) were laid out between two sheets of clean white kitchen towels. Participants were seated in front of the covered spoons and asked to put on a blind-fold before tasting began. Participants were then invited to place each spoon into their mouths and experience the taste of each spoon. Participants were free to suck and lick the spoons in any way they wished but were asked not to use their teeth (to prevent scratching of the spoons).

Whilst tasting each spoon, participants were asked to respond orally to the taste of the spoon by rating in accordance with the following subjective adjectives read to the participant by the experimental supervisor: cool, hard, salty, bitter, metallic, strong, sweet, and unpleasant. For example, the experimental supervisor would say "metallic" and the participant would give a value between 1 and 7, with 1 being not at all metallic and 7 being very metallic.

The order of the spoons was randomised for each participant, although the first spoon was always one of the two stainless steel spoons which was used to acclimatise the participant and this data was discarded from the study. The order of the adjectives was not randomised and was given in the order listed above.

A glass of still room temperature mineral water was available for each participant to drink after each spoon in order to cleanse and neutralise their palate if desired. Participants were instructed not to embark upon the next spoon until they felt that their mouth was in a neutral state

Results

The subjective experiential data, once normalized and statistically analysed, have been correlated for principal component analyses, where graphs reveal the relationships between the types of words rated as being a good description of the taste of a particular material. The data have also been plotted against the reduction potentials of the metals to show the correlation between the experiences of taste and the specific metals' reduction potential, thermal conductivity and electrical conductivity. In addition to the formal data gathered through the participants' rating the taste of each spoon, video and audio recordings taken throughout the experiment enabled the extraction of pertinent quotations and the identification patterns of non-verbal behaviour, reaction and reflection displayed by the participants.

References

1. Miodownik, M. A. Developing the sensoaesthetic properties of materials, Journal of Pure and Applied Chemistry, Vol.79, No.10, pp.1635-1641, 2007.
2. M. F. Ashby and K. Johnson. The Ar t and Science of Materials Selection in Product Design. Butterwor th Heinemann, Oxford, 2002.
3. H. T. Lawless, D. A. Stevens, K. W. Chapman, and A. Kur tz. Metallic taste from electrical and chemical stimulation. Chem. Senses, 30:1–10, Sept 2006.
4. B. Lindemann. Receptors and transduction in taste. Nature, 413:219–225, 2001.
5. Miodownik M.A. Taste of Spoon, Materials Today, June 2008, p.6.

Interdisiplinarity and sound environment research.

Frans Mossberg

Sound Environment Centre, musicology, Lund University, Sweden
fransmo@glocalnet.net

Introduction

When I first heard of the Minet network I immediately felt drawn its interdisciplinary perspectives and also its subject of measuring the impossible. I felt this is what I am trying to do all the time. My own background is in musicology but since a few years I am manager and coordinator of Listening Lund Sound Environment Centre at Lund University in Sweden. It is known to be the first interdisciplinary research centre created with an aim to especially coordinate research on sound and soundscape issues. Ranging from acoustics to medicine and psychology as well as musicology and cognitive studies, soundscape research addresses many interdependent areas and topics. To be able to get a more complete comprehension our soundscapes there is a need for this multitude of areas to be synchronized and be put in relation to each other.

Sound and sound environments are truly complex phenomena that are dependent on human perception and how sound is interpreted by the human mind and body. As sound is always perceived in combination with other sensory sensations and inputs, studying the reactions to sound in man involves measurements of a multitude of qualities, raising a need of quantification of many parameters, including some that have yet to be defined. The existence or non existence of auditive or acoustic space can largely affect our sense of security and well-being or the lack thereof. By acoustic space I mean a sound environment that allows you to hear distant or weak sounds.

I think the sound environment centre at Lund university share a common interest in research areas in MINET network, an interest that could really be considered Measuring the Impossible, and I am glad to take a part of the discussion here.

If you would make a check list for sound environment research out of the areas of focus mentioned in the call for papers for this conference, it could read something like this:

Sound environment studies involving multisensory perception as well as cognition and emotion are also about ethics, in how our ways of dealing with sound, as well as generating sounds, reflects individual and social behaviors. It is of course also about data interpretation and analysis. Especially subjects like acoustics and audiology are largely dependent on instrumentation, measurement techniques and protocols, raising questions of uncertainties and theory, and perhaps even standardization. As you see, I’ve here used all the subjects of focus mentioned in the call for this workshop.

Sound Environment Research

Sweden might seem like a quiet place in comparison with other parts of Europe. It has lots of reasonably peaceful countryside and a moderately trafficked road system compared to many sound environments in central Europe and other where. The first reaction from fellow sound environment warriors around the globe might be; what are you complaining about?

Nevertheless, the large areas of wilderness and rural areas have provided Sweden with a constant reference to fairly peaceful soundscapes that has made many people notice, hear and worry about the differences between noise and tranquility, and to appreciate natural environmental values enough to miss them when they are gone. “You sure do miss the silence when it’s gone”, Robbie Robertson of the Band wrote in the song “Where do we go from here” in the late sixties and the words still rings true.

At Lund University situated in the south of Sweden, a few years ago the thought was born to constitute an interdisciplinary centre for research and information on our sound environment. The centre was designed after a preliminary study made by Henrik Karlsson, whom some of you might be familiar with. This was a study largely relying on his longtime work and engagement in soundscape issues. Together with the diplomacy and energy of professor of musicology at Lund University, Mr. Greger Andersson, this study managed to convince the vice chancellor to provide the funding for a centre that was finally to be baptized *The Sound Environment Centre* at Lund University.

The main thought behind this was that the totality of sound environmental research is a truly complex one and one that involves many different perspectives, in a wide array of academic traditions and faculties. This goes for both the defining of the problems as well as searching for solutions and answers.

To illustrate the situation with a simple picture drawn in the preliminary study: the general situation of sound and society we have to deal with might be seen as large commode with many different drawers. Each one in its own way dealing with sound and sound environments. One drawer for ethics, one for acoustics, one for health medicine, one for sound design and so on. One for road traffic… and never shall they meet! The situation becomes similar when we come to look at academic subjects and research.

Questions of soundscapes, health and noise problems are slowly emerging to a common awareness today. Research and invention are being done on detailed levels and must avoid the risk of fragmentation, and the Sound Environment Centre at Lund University in Sweden believes that it is important to create and stimulate networks promoting interdisciplinary research to be able to give justice to this totality of the soundscape issues.

One of many characteristic issues is the intangibility of sound: when its there, its there and when its gone, it’s gone as if it’s never been there, leaving no scars (if your hearing hasn’t got seriously damaged of an extreme exposure that is, or your blood pressure or stress hormones hasn’t discretely risen as an effect of the traffic outside your bedroom window, that is. The intangibility aside, the costs of noise doesn’t disappear. The more we take into account prevention and health care that can be related to noise, the costs of noise rises monumentarily.

Organization

The centre has a board of representatives of academic subjects as acoustics, ergonomics, psychology, musicology, audiology, environmental medicine, health economics etc. and has been provided with a three year period of funding for basic functions, such as keeping a coordinator, daily costs of office tasks, printing costs etc. In addition to this, the centre applies separately for funds for the specific research projects to external sources.

In addition to the board the centre, a research reference group has been put together as well as an international group of mentors connected with the centre. The centre has also initiated an informal meeting with other interdisciplinary resources at the university and representatives of the industry working with sound environmental problems such as Volvo, Sony Ericsson, Trelleborg and others. It keeps its own website (www.ljudcentrum.lu.se) on the Lund university server and promotes networking in general when and wherever possible. Plans are being made for a local *Sound Environmental Advisory Board* and a *Friends of the Sound Environment* network open to funding by private persons as well as by cooperations.

The centre has established cooperation with the Swedish counterpart to the International League for the Hard of Hearing, *Hörselfrämjandet,* in promoting the annual *International Noise Awareness Day* in April. The centre has also received the prestigious *Sound Reward* last year from the *Swedish Acoustic Society* for its research and work.

The centre was evaluated by the university after its first three year of activities and was described as an activity (quote :) "bringing substantial added value to the university". It has recently also received a new three year funding for further development of interdisciplinary research that today provides seed money for a line of new projects..

With the mission to provide a forum for a multi- and interdisciplinary perspective the centre has arranged a series of much appreciated symposiums addressing special topics such as "Noise and health", "Seductive Sounds", "Operational sounds", "Dangerous sounds" and "Sound cognition and learning". Further topics that have been addressed are "sounds and emotional disturbances as Schizophrenia and ADHD as well as "Sound Design" and the use of sounds and silence in spiritual and religious movements of various kinds. Each symposium producing a collection of published papers.

Projects

The centre is by now responsible for a number of ongoing research projects and is beginning to receive funding from various sources. Among ongoing and previous projects may be mentioned:

Traffic noise, recreational values and health

investigating associations between residential exposure to traffic noise, positive recreational values of the natural surroundings, and health, using extensive longitudinal data from a baseline and a follow-up survey combined with Geographic Systems (GIS) data. Some of the major aims are: 1: Improved tools for modelling of exposure to traffic noise and access to positive recreational values, 2) To explore associations between these aspects of the residential environment and neighbourhood comfort, physical activity, performance, recovery, overweight and hypertension.

Health effects of simultaneous exposure of airborne particles and noise
Another large project associated with the centre investigates simultaneous exposure of airborne particles and noise and if this can have noticeable combined health affects on humans. This project will involve cooperation of researchers from acoustics, cardiology, laboratory medicine and ergonomics.
As a follow-up to this project a further study in collaboration with researchers from Copenhagen and Gothenburg, will study how noise actually can affect the walls of individual cells on a micro/cellular level.

Speaker comfort and acoustics
lead by ass.prof. Jonas Brunskog investigating the stress on voice production by different acoustic conditions with an aim to find guidelines for design of acoustic environments with focus on speakers as teachers and lecturers. This project has received funding from AFA – an insurance institute in Sweden.

Railway noise at different climatic conditions
a visualization of how noise of trains move through the landscape at different conditions of dampness and temperature – i.e. "atmospheric inversion". This important project presents a film of the movement of the actual noise of trains affecting an exposed village close to Malmoe in an open landscape in southern Sweden. The film has been used in discussions with politicians on the planning of new railroad tracks through the area. This project was led by professor in landscape planning Erik Skärbäck at Alnarp.

Eye movement and cognition disturbance and exposure to noise, sound and music
Using advanced eye movement equipment at the laboratory of humanities in Lund the project will study how reading and understanding is affected by noise and music, wanted or unwanted. This project wants to create a deeper understanding of the reading behaviour to background sound. This is a joint interdisciplinary project between cognitive studies, psychology and musicology. I think it also especially embarks on the Measuring the impossible domain. When trying to measure such a simple thing as how the act of studying/reading is affected by sound levels when listening to music an immense amount of difficulties as music in itself, any music, is so rich in meanings and parameters that it becomes difficult to filter out what to measure. As music is an auditive periodization of time in different frequencies it cannot be substituted by a simple non-modulating signal, making it difficult just choosing the appropriate sound stimuli. This is something I would gladly discuss.

Noise economics A project run at LUCHE *The Lund Centre of Health Economics* looking at the individual's willingness to pay for reduced health risks by using a Contingent Valuation method.

Sound as one part of a totality of sensory impressions in Virtual worlds
At Ingvar Kamprad Design Centre and the institute of ergonomics Prof Gerd Johansson will look at how sound interact with the totality of sensory impression in virtual reality environments. This project will involve full scale virtual laboratory technologies in Lund.

Sound of nature as sounds of wellbeing
Together with the SLU department of Landscape Planning at Swedish University of Agricultural Studies, a new study will look at what happens to sensory awareness when common rooms are fed with “natural” sounds as those of low amplitude bird song and sounds of woods and water.

Conclusions
All in all the existence of an experiment like Listening Lund The Sound Environment Centre at Lund university within the framework of a resourceful university like that of Lund shows that interdisciplinary collaboration opens up new possibilities and horizons. The university already possesses unique skills and credentials in fields relating to sound, such as acoustics, medicine, working environments, and architecture. Areas that are now brought together and strengthened in a number of research projects and other activities. The Centre has been enhanced with closer contacts with related disciplines, potential financiers, and other partners. This work still continues as well as the series of symposiums.

References
H. Karlsson, “Towards a multidisciplinary understanding and handling of the human sound environment”, Presentation and paper at the colloquium „*Construire avec les sons*“, Paris 17-18 March, 2005 (2005).

Reports from Sound Environment Centre at Lund University (Skrifter från Lyssnande Lund Ljudmiljöcentrum vid Lunds universitet), 1 – 7 (all but no.6 in Swedish). Rapport nr 6, *Sounds of History*: Cajsa S. Lund, “Prehistoric Soundscapes in Scandinavia”, Jens Holger Rindel, “Roman Theatres and their acoustics”, Charlotte Hagström, “Sounds now and then”, Jonas Brunskog, “Building acoustics in old houses”.

H. Karlsson, *Lyssnande Lund – Förstudie om ett tvärvetenskapligt ljudmiljöcentrum vid Lunds universitet*, Ljudmiljöcentrum Skriftserie, Lund (2006).

Website: www.ljudcentrum.lu.se

Measurement for a more visible world: colour contrast and visual impairment

Hilary Dalke*, Gareth Conduit†, Bryce Conduit[+], Alessio Corso*

** Design Research Centre, Kingston University*
† Theory of Condensed Matter Group, Cavendish Laboratory, Cambridge
[+] Department of Materials Science and Metallurgy, University of Cambridge, Cambridge

Corresponding author: h.dalke@kingston.ac.uk

Abstract

Visual contrast between adjacent surfaces is a requirement of Building Regulations Part M, 2004, the Disability Discrimination Act (DDA) 2004, for the design of inclusive environments, and products and services for Visually Impaired People (VIP). There are nearly 3 million people in the UK who have some form of low vision. Despite guidelines, standards and regulations, there is no 'tool' to help contractors, architects, designers and access consultants evaluate what exactly constitutes 'good colour contrast' in their projects. No definitive advice exists on how to achieve effective contrast specification for materials. Currently contrast assessment may be too complex a process for access personnel to devote time and resources to. Existing colour measurement technology (spectrophotometry) is too expensive (circa £4 - 8,000) and over-specified (multiple colour spaces) for simple and easy contrast evaluation.

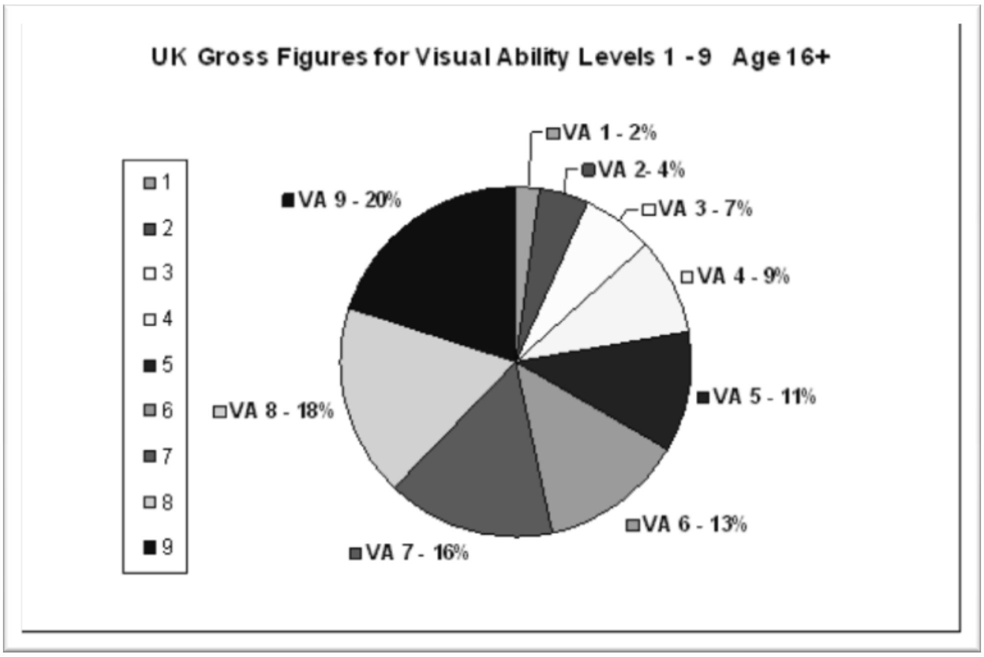
Although it has been known for some time that adequate contrast is essential for the perception of the world for people with low vision[1], until recently the mechanisms for the provision of those interventions for the agencies that require that information - the methods for achieving success - have not been fully mapped out. Research has been carried out over the past four years that developed from useful observations on an EPSRC/Link research project[2]. The detailed measurements of 380 objects (seen by VIPs) and their environs – namely the light reflectance value (LRV), size, distance and lux – on 'real world' sites were collated and analysed. This work resulted in the creation of a first generation algorithm colour contrast prediction model for software, and firmware to be used in a tool microchip.

This colour contrast model - developed by Dalke, Conduit and Conduit for the benefit of improved visual acuity for the visually impaired population, enables the architect, designer or access consultant and developers of the built environment to predict whether a VIP is able to see an object, text or element of a building before design and installation.

The model required beta-testing in the lab and observations conducted on what occurs in a complex near 'real world' setting; the presentation of this paper will describe the positive verification of the model with a test; this was carried out with 10 participants. The results from the lab tests will also demonstrate the differences between the perception of backgrounds and objects of varying grayscales by the visually impaired participants.

Background

One of the five key factors of the colour contrast model, in both contrast assessment and specification, is the profile of the visually impaired population (Fig 1). Exact figures on the size of the VIP categories of visual ability are difficult to obtain; however it is likely that only around 2% of the registered VIP population (classified as severely impaired or blind) have no ability *'to see any light at all that may be coming through a window'*, and 4% may just be able to perceive light (Fig 2). From data gathered it can be seen that the vast majority of the visually impaired population – 94% - have varying increasing levels of residual vision from V3 to V9; V10 being full vision. Consistent and accurate use of colour contrast for product or environmental design would be efficacious for this community and others. It should be noted that experts in the field recognize that the number of registered VIPs does not fully reflect the actual scale of low vision in the UK. Many people with poor visual acuity fail to present themselves to either GPs or opticians for early diagnosis so statistics on the visually impaired population are thought to be much larger than the figures recorded.



Source : Dalke et al 2008, Grundy E.[3], Douglas, G.[4]

Fig 1 UK Gross figures for visual ability levels V1 – 9 Age 16+

- 3 million people in the UK population live with some form of low vision
- 6% of the VIP population has a VA level of around V1 and V2, the most severely sight impaired (blind).
- 94% of the visually impaired population registered as blind or partially sighted may have good residual or useful fields of vision.

Visual Ability
• V1 – Cannot tell by the light where the windows are • V2 – Cannot see the shapes of furniture in a room • V3 – Cannot see well enough to recognise a friend if close to his/her face • V4 – Cannot see well enough to recognise a friend who is at arm's length away • V5 – Cannot see well enough to read a newspaper headline • V6 – Cannot see well enough to read a large print book • V7 – Cannot see well enough to recognise a friend across a room • V8 – Has difficulty recognising a friend across the road • V9 – Has difficulty reading ordinary newspaper print • V10 – Full vision ability *Ability level is measured with any desired vision aids.

Source : http://www-edc.eng.cam.ac.uk/betterdesign/usercap/vision/vision11.html

Fig 2 Visual ability categories

Results

Colour contrast model predictions were checked with VIP participants and shown to be robust when compared with data generated in the beta lab tests. The results showed a consistent trend across ten participants; there was a difference between perceptions of patches on the light background/patch sets and dark background/patch sets. As can be seen in (Table 1), where there is an LRV difference of 22 points in all sets, the distances at which the patches were observed were greater and more successful when the darker shade combinations were used. Dark background and patch sets scored considerably higher visibility at 1155 metres total distance with participants, whereas the reverse lighter combinations, scored much less at 680 metres (Table 1). Although both sets had a 22 points difference between background and objects, the lighter the background and patch set the closer proximity needed to see the contrast difference.

Table 1 Testing of 5% and 27% LRV and 71% and 93% LRV patches and backgrounds (both with contrast difference of 22). The results for greatest distances from which the patches were seen was 1155 metres (63%) for darker backgrounds and patches; and a greatest distances total of 680 (37%) for light backgrounds and patches. All testing of backgrounds and patches were with 22 contrast difference between backgrounds and the patches.

Participant. Ref No	**8**	**3**	**9**	**7**	**6**	**10**	**1**	**2**	**5**	**11**		TOTAL
Visual Ability (VA) 2 -10	**2**	**2**	**2**	**3**	**4**	**5**	**6**	**6**	**8**	**10**		
Object size 15cm												
RESULTS All with contrast difference of 22 over a 10 metre course												
Dark 5%/27% (22)												
Background/Patch Distance seen	0.5	1	2.5	7	8.5	8	9.5	1.5	9.5	10		**580 metres**
Dark 27%/5% (22)												
Background/Patch Distance seen	1	1	3.5	5.5	5	6.5	10	6	9	10		**575 metres**
Difference between reversal	.5	0	1	1.5	3.5	1.5	.5	4.5	.5	0	**13.5**	**1155 metres**
								Distances seen dark sets				**63%**
Light 71%/93% (22)												
Background/Patch Distance seen	0.5	0	1.5	5	5	3.5	4	4	10	10		**340 metres**
Light 93%/71% (22)												
Background/Patch Distance seen	3	1.5	3	3.5	1.5	0.5	3	4	7	10		**340 metres**
Difference between reversal	2.5	1.5	1.5	1.5	1	3	1	0	3	0	**15**	**680 metres**
								Distances seen light sets				**37%**

Two objectives of the study were achieved. Firstly, the utility of the prediction software was rigorously tested and the accuracy of the software established against the beta test results. Secondly, the 'real world' lab tests demonstrated that a contrast of 22 of dark objects on dark backgrounds were visible at a greater distance (63%) than a contrast 22 of light objects on light backgrounds (37%) by as much as 26% over a 10 metre test course.

References

1. Bright, K., Cook, G., Harris, J. Colour, contrast and perception: design guidance for internal built environments 1997 - University of Reading
2. http://www.dft.gov.uk/stellent/groups/dft_science/documents/page/dft_science_033473.pdf
3. Grundy E, Ahlburg D, Ali M, Breeze E, Sloggett A, Disability in Great Britain: results from the 1996/97 disability survey Technical Report 94. 1999, Dept of Social Security: London
4. Douglas G., Corcoran C., Pavey S., Network 1000: Opinions and circumstances of visually impaired people in Great Britain: report based on

over 1000 interviews. August 2006, Visual Impairment Centre for Teaching and Research, University of Birmingham.pg31
5. www.cromocon.com

Keywords: Colour contrast, Light Reflectance Value, Inclusive Design, Visual Impairment, Visual Acuity

Subjective and objective measurements in the context of sonic interactions

Guillaume Lemaitre, Patrick Susini, Nicolas Misdariis, Olivier Houix

IRCAM, 1 place Stravinsky, 75004 Paris, France
{lemaitre, susini, misdarii, houix}@ircam.fr

This presentation provides an overview of three studies developed during the CLOSED project. These studies had the primary purpose to address the question of the role of sounds in highly interactive everyday artifacts that are believed to appear in a very near future in our daily lives. These objects (at the moment only design or research prototypes) are embedded with sensors and actuators, and create situations where users are manipulating a device that continuously and dynamically generate sonic feedbacks in response to the manipulation, and which in turn are meant to influence the user's manipulation. These situations are referred as *sonic interactions*. To address the role and influence of sound in sonic interactions, theses studies were interested in sound perception, cognition, and in the emotional reactions induced by the sounds. However, these studies all faced the problem that the very nature of sonic interactions prevent the strict application of any classical psychoacoustical experimental framework in which subjects are questioned about their perceptions while passively listening to sounds controlled and prepared in advance by the experimenter. We review in this presentation the experimental frameworks that were developed to address this issue.

The first study [Lemaitre et al., 2009a], focusing on a specifically-designed artifact (the *Spinotron*), addresses what is probably the most basic assumption of sonic interactions: does the sonic feedback in a sonic interaction influence and guide the user's manipulation? The methods used in this study are mainly based on measuring the user's performance in trying to fulfill a task (the experimental session being designed as a game), and the results positively conclude about the potentiality of the sound to guide the user's fine gesture. The second study [Lemaitre et al., 2009b] investigates the influence of the sonic feedback in more details, by focusing on the emotional reactions induced by the sounds (and by the manipulation) during the interaction. This study uses another interface, also specifically designed for the purpose of experimentation, called the *Flops*. It also requires a user to play a game, and uses self-reports of users' feelings. Among other conclusions, this study stresses the importance of the *naturalness* of the sounds. Therefore, the third study [Susini et al., 2009] focuses on the influence of the naturalness of the sonic feedback on the perception of the usability in a context of use with a simple device (here the keyboard of an Automatic Teller Machine ATM),, by comparing users' judgments before and after manipulating the interface. The emotional reactions induced by the different sounds of the interface are also studied.

The following paragraphs briefly report the details of these studies.

The Spinotron Study: can the sonic feedback of an interactive device be used to guide the manipulation of an interface?

This study questions the role of sound in sonic interactions. It is based on an interface that we refer to as the *Spinotron*. It is a tangible, one degree-of-freedom controller that is endowed with both sensing and synthesized sonic feedback, the design of which was based on the metaphor of the rotation of a virtual ratcheted wheel, driven in a manner analogous to a child's toy consisting of a spinning top. Whereas many of the methodologies that have been developed to study human-computer interfaces generally use reaction times or movement time, in the design of sonic interactions sensory-motor experience ``may not be best indexed merely by chronometrical methods" [Welsh et al. 2007, p.29] and new methodologies may be required. Therefore, following the examples of [Rath and Schleicher, 2008], the study focuses on the performance of the users when required to play a game with the Spinotron

Three experiments were conducted to assess two key aspects. First, a comparison of sound source identification was made between three cases: passive listening to temporally static sounds; passive listening to dynamically evolving sounds; and listening to sounds generated through active manipulation of the artifact. The results show that control over the sound production process influences the material of the objects in interaction identified as the source of the sounds.

Second, in a learning experiment, users' performance with the Spinotron device was compared between a group of participants that were provided only with passive proprioceptive information, and for another group who were also presented with synthetic sound produced by the artifact. The results indicated that the sound, when present, aided users in learning to control the device, whereas without the sound no learning was observed.

The Flops study: assessing emotional reactions in sound design

Whereas the Spinotron study showed that the sounds used in a sonic interaction influence the users' manipulation, the Flops study investigates this influence in more details, by focusing on emotional reactions. Sounds, like many other stimuli and situations, have the power to influence people's emotional reactions. Many studies of emotional reactions to sound, however, use experimental situations in which listeners are passively listening to sounds. Whereas sounds can influence emotional reactions of the listeners, manipulating an object with a specific purpose probably also influences the affective reactions of the user, depending on how easy, disturbing, rewarding, comfortable, etc. is the interaction, with respects to the goals of the user. The Flops study therefore explore the emotional reactions induced by the sounds, when the sounds are dynamically generated by the user's manipulation of a device, manipulation that also influences the emotional reactions.

There are two questions addressed by the Flops study: 1. Can the relationships between sound parameters and emotional reactions found in other studies ([Västfjäll et al., 2003] in the case of passive listening of aircraft noises) be generalized to other sounds (here impact sounds)? 2. Are these relationships modified when the users, instead of passively listening to sounds, are generating the sounds by continuously interacting with an object?

In this study, we use an interactive object augmented with sounds: the Flops glass. It consists of a glass embedded with a tilt sensor allowing it to control the generation of impact sounds when tilted. It implements the metaphor of a glass full of virtual balls that may be poured out of it. The sounds generated at each impact are selected or synthesized in order to assess the influence of the sound parameters on the affective reactions of the users.

In a first Experiment, participants are required to watch a set of videos displaying a user pouring virtual items out of the Flops glass. Using a classical methodological framework, they have to report their feelings (considered as the conscious reflection of the on-going emotional reactions [Juslin and Västjäll, 2008]) by providing judgments on three scales: valence, arousal and dominance, using the Self-

Assessment Manikin [Bradley and Lang, 1994]. The images in the videos are all the same, and only the sounds changed. The sounds were created on the basis of conclusions of [Västfjäll et al., 2003] that have suggested that the emotional reactions to aircraft noises are influenced by several aspects of the sounds: sharpness, tonality and naturalness. In the experiment, the passive listening framework is very close to Västfjäll's one. The results show, in agreement with Västfjäll, that the spectral centroid (measuring the perceived sharpness of the sounds), and the naturalness of the sounds (though indexed through different methods) have a significant influence on the reported feelings. On the contrary, the results did not show any significant influence of any measure related to tonality, which is not surprising considering the nature of the sounds used here (short impact sounds sequenced in various temporal patterns).
The second experiment introduces the manipulation of the Flops. In this experiment, the participants had to play a game, that of using the Flops to pour exactly 10 balls. Different difficulty levels are set, by changing the parameters of the model underlying the interaction with the Flops, and three sounds selected from the results of the first experiment are used. The participants have to report their feelings after performing the task, using the same procedure as in the previous experiment. The results show that the affective reactions are mainly influenced by the difficulty of the task, and by the score at the game. In addition to, and despite the large influence of the manipulation task, the results show that the different sounds are still influencing the valence of the feelings reported by the users: natural sounds with low spectral centroids improves the valence of the reported feelings, compared to synthetic sounds with higher spectral centroids.

The ATM study: influence of the sonic feedback on the subjective and objective usability of the interface of Automatic Teller Machine

This study is interested in the sounds of the keyboard of an automatic teller machine (ATM). It builds upon the conclusions of the Flops study, highlighting the importance of the *naturalness* of the sounds in a sonic interaction, and seeks to elaborate more on the definition of the *naturalness*. More specifically, it focuses on the relationship between the action (striking a key) and the resulting sound. *Natural sounds* here are meant to imply a perceived causal relation between an action and the resulting sound (referring to the ecological viewpoint by J.J. Gibson [Gibson 1966] a perceived natural interaction could be considered as a perceived affordance). For instance [Rath and Schleicher, 2008] defined a natural interaction as inducing a "spontaneous understanding of interaction principles on the side of a user". On the contrary, when no causal relationships between the action and resulting sound can be understood, the sounds are considered as non-natural.
The goal of this work is to study the influence of a natural sonic feedback on the perceived usability and on the feelings reported by the users before and after using the ATM interface. The initial assumption motivating this study is summarized by the intuition reported in [Norman, 1999]: "I believe that our reliance on abstract representations and actions is a mistake and that people would be better served if we would return to control through physical objects, to real knobs, sliders, buttons, to simpler, more concrete objects and actions". In short, the question addressed by the study is whether natural sounds would lead the interface to be perceived as more usable than non-natural sounds.
The experimental procedure used in the ATM study is based on the framework developed in [Tractinsky et al., 2000]. Different sounds were created, leading to three levels of naturalness: causal, iconic, and abstract. In addition, two levels of controlled

usability of the system are used: a low level and a high one. The experimental procedure consists in requiring the participants to judge the sounds of the interface and the usability of the interface on several scales, before and after manipulating the ATM to perform a set of predefined tasks. The scales were related to the naturalness of the sounds, to the usability of the interface and to the feelings of the participants (valence and arousal). This procedure therefore examines if the user's initial impressions hold after the practical use of the device. The results suggest that the acceptance of an iconic (designed) sound is weaker when the system is not working properly (low controlled usability) than when the system is working properly, which is not the case for the causal sounds, which are still well accepted.

Refrerences

[Bradley and Lang, 1994] Bradley M. M. and Lang P. J., "Measuring emotion: the Self-Assessment Manikin and the semantic differential", Journal of behavior Therapy and Experimental Psychiatry, volume 25(1), pp. 49-59, 1994.

[Gibson 1966] The Senses Considered as Perceptual Systems (Houghtin Mifflin, Boston), 1996

[Juslin and Västfjäll, 2008] Juslin P. N. and Västfjäll D., "Emotional responses to music: the need to consider underlying mechanisms", Behavioral and Brain Sciences, vol. 31(1), pp. 559-621, 2008

[Lemaitre et al., 2009a] Lemaitre G., Houix O., Visell Y., Franinovic K., Misdariis N. and Susini P., "Toward the Design and Evaluation of Continuous Sound in Tangible Interfaces: The Spinotron", International Journal of Human-Computer Studies, special issue on Sonic Interaction Design, in press, 2009

[Lemaitre et al., 2009b] Lemaitre G., Houix O., Visell Y., Franinovic K., Susini P., "the Flops glass: a device to study emotional reactions arising from sonic interactions", Proc. of the Sound And Music Conference", Porto, Portugal, 2009

[Norman, 1999] Norman, D. A. "Affordance, conventions, and design", Interactions 6 6, 38-43.

[Rath and Schleicher, 2008] Rath, M., and Schleicher, R. "On the Relevance of Auditory Feedback for Quality of Control in a Balancing Task," Acta Acustica united with Acustia 94, pp. 12-20, 2008

[Susini et al., 2009b] Susini P., Misdariis N., Houix O., Lemaitre G. "Does a natural feedback affect perceived usability and emotion in the context of use of an ATM?", Proceedings of the Sound And Music Conference", Porto, Portugal, 2009

[Tractinsky, 2000] Tractinsky, N., Adi, S.-K., and Ikar, D. "What is Beautiful is Usable", Interacting with Computers 13, 127-145.

[Västfjäll et al., 2003] Västfjäll D., Kleiner M. and Gärling T., "Affective reactions to Interior Aicraft Sounds", Acta Acustica united with Acustica vol. 89: 693-701, 2003

[Welsh et al., 2007] Welsh, T. N., Weeks, D. J., Chua, R., Goodman, D., “Perceptual-motor interaction: some implications for HCI”. In: Sears, A., Jacko, J. A. (Eds.), The Human-Computer Interaction Handbook: Fundamentals, Evolving Technologies and Emerging Applications, 2nd Edition. CRC, Ch.1, pp. 27--41.

Measurement of physiological parameters using ultra-high impedance electric potential sensors

H. Prance*, P. Watson, S. T. Beardsmore-Rust, C. J. Harland, R. J. Prance

Centre for Physical Electronics and Quantum Technology, School of Engineering and Design, University of Sussex, Falmer, Brighton, BN1 9QT, U.K.
* prance@sussex.ac.uk

Introduction

In the fields of human perception, human-machine interfacing, and assistive technologies there is considerable interest in the development of dry-electrode, capacitive and non-contact sensor systems for the measurement of human physiological signals[1,2,3,4]. These include the detection of the electrocardiogram (ECG), the electrooculogram (EOG), the electromyogram (EMG) and the electroencephalogram (EEG). The aim is to provide sensors which are non-invasive, if possible non-contact, user-friendly, robust, and sensitive to the complex and subtle physiological signals associated with human perception, cognition and control.

We describe an ultra-high impedance electric potential sensor technology which has all of these characteristics. It operates in a passive mode, through capacitive coupling, and is therefore entirely non-invasive. It is capable of acquiring signals with no resistive contact to the source and, in given circumstances, no physical contact either. The sensor is straightforward to use, requiring no skin preparation or specialised placement techniques. It is encapsulated and highly robust and is extremely sensitive to physiological signals. It is configurable to provide a range of spatial resolutions down to 1μm and is suitable for integration into high density imaging arrays. We illustrate these characteristics with examples of the application of this technology to the detection of a wide variety of physiological signals including heart rate, respiration, EMG, EOG, blink rate and ECG.

The electric potential sensor

The electric potential sensor (EPS) is a high impedance measurement system with ultra-low capacitance capable of making non-invasive measurements in both the electrical and physical sense. It makes true voltage measurements through weak capacitive coupling (typically <1pF) and is scalable over a wide range of spatial resolutions. In the contact mode, the capacitive coupling is provided by a thin insulating layer which presents a well-defined, constant, coupling to the surface of the body. In the non-contact mode, the capacitive coupling is determined by the distance between the sensor electrode and the source and may be affected by any relative movement between the two.

The ultra-high impedance performance of the sensor is achieved using a combination of well known positive feedback techniques, together with a novel technique for supplying a stable DC bias current without compromising the intrinsic input impedance of the device. The result is an integrated electrode/sensor combination. An accurate differential measurement is usually made using a pair of these sensors, thus removing the need for an additional reference electrode. The sensors are battery operated and may be directly interfaced and powered via a USB interface if desired.

Physiological measurements

The advantages of the EPS for the measurement of physiological signals of interest for human perception, cognition and interpretation may be illustrated using specific examples.

The non-contact detection of heart signals can be used to monitor heart rate variability and respiration. Using a single EPS, we are able to detect combined heart rate and respiration up to 40 cm from the surface of the body in an open unshielded environment[5]. The cardiac and respiration signals can be separated using simple digital filtering techniques and the respective rates derived. In Figure 1 we show an example of such a combined signal collected by a sensor positioned on front of a subject.

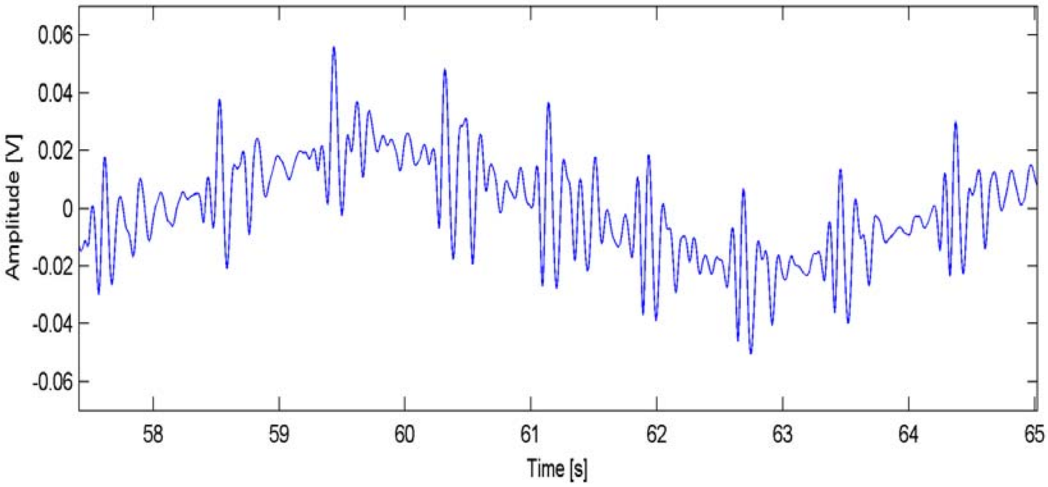
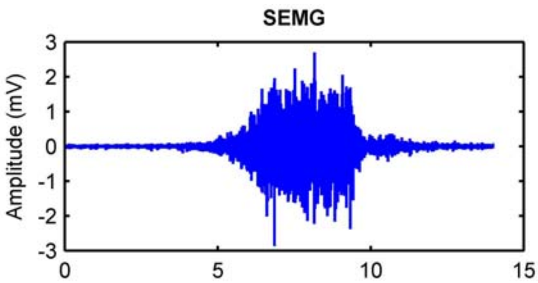


Figure 1. Unprocessed data from an EPS sensor positioned 40 cm from the front of a subject showing both respiration (low frequency) and cardiac (high frequency) signals.

The significant characteristics of this measurement are the following: it is entirely passive, relying on the measurement of the local electric field as modified by both the electrophysiological signal due to the heart and the movement of the chest cavity; it is highly sensitive, due to the ultra-high impedance of the sensor; and it is a remote measurement in an unshielded environment, achieved by adapting the sensor so that it is able to reject external noise at particular frequencies.

The application of the EPS to surface, insulated measurements, similar to dry-electrode techniques, is illustrated by the detection of EMG signals from the surface of the arm. Figure 2 shows the surface EMG (SEMG) arising from activation of the flexor carpi radius (FCR) muscle acquired using a 20 mm diameter surface contact sensor.

a)



b)

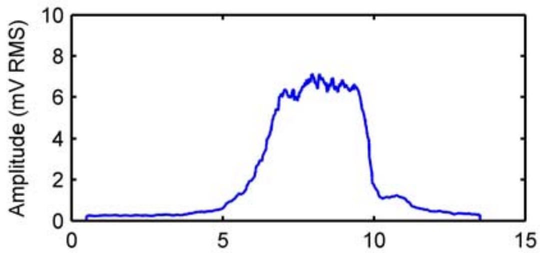


Figure 2 (a) SEMG from the FCR muscle, raw data (b) RMS amplitude of data from (a).

The significant characteristics of this measurement are: its simplicity, requiring no skin preparation and the attachment of the sensor using a simple elasticated band; and its high sensitivity, again due to the ultra-high impedance of the sensor which does not load down the source signal. We have also demonstrated SEMG signals measured using a 25 μm sensor in the same position, which indicate that we are able to discern individual motor unit action potentials[6]. In other applications, we have shown that the spatial resolution is, in principle, as high as 1 μm[7].

A similar surface measurement has been used to acquire the EOG and eye blink rate[8]. These measurements have demonstrated clear, independent signals arising from eyeball movement in the horizontal and vertical directions, and from both fast (~ 0.2 s) and slower (~ 0.5 s) blinking. Once again, the measurement is extremely simple, with no skin preparation, and provides clean, large amplitude signals.

Finally, we have demonstrated that in the contact mode, where the coupling to the body is well-defined, the EPS is capable of acquiring extremely high quality, clean ECG signals[9]. These signals require only two insulated electrodes, placed on the body on either side of the heart, e.g. on the fingertips or wrists, and can be monitored remotely with the subject ambulatory[10]. In addition, a 4-element array of sensors placed on the chest has been shown to provide equivalent information to the standard 7-lead ECG[11]. This, and other work on EPS arrays[12], demonstrates that these sensors in close proximity do not suffer from cross-talk and are capable of implementation in high density array formats.

References

[1]Garcia, F Zaccone, R Ruff, S Micera K-P Hoffmann, P Dario "Characterization of a New Type of Dry Electrodes for Long-Term Recordings of Surface-Electromyogram" Proc 2007 IEEE 10th International Conference on Rehabilitation Robotics, June 12-15, Noordwijk, The Netherlands (2007)

[2]N P Reddy, V Gupta "Toward direct biocontrol using surface EMG signals: Control of finger and wrist joint models" *Med. Eng. Phys.* **29**, 398-403 (2007)

[3]A Bulling, D Roggen, G Tröster "Wearable EOG Goggles: Eye-Based Interaction in Everyday Environments" Proceedings of the 27th international conference extended abstracts on Human factors in computing systems Boston, MA, USA, pp 3259-3264 (2009)

[4]F Popescu, S Fazli, Y Badower, B Blankertz, K-R. Muller "Single Trial Classification of Motor Imagination Using 6 Dry EEG Electrodes" PloSOne Issue 7, July 2007, accessed from http://www.plosone.org/article/info:doi/10.1371/journal.pone.0000637 29 July 2007.

[5]RJ Prance, ST Beardsmore-Rust, P Watson, CJ Harland, H Prance "Remote detection of human electrophysiological signals using electric potential sensors" *Appl. Phys. Lett*. **93**, 033906 (2008)

[6]H Prance, P Watson, RJ Prance, CJ Harland, S Beardsmore-Rust, A Aydin "High spatial resolution dry-electrode surface EMG acquisition system" accepted for the Proceedings of AAATE 2009
August 31 – September 2, Florence, Italy (2009)

[7]RJ Prance, TD Clark, H Prance, A Clippingdale "Non-contact VLSI imaging using a scanning electric potential microscope" *Meas. Sci. Technol.* **9** 1229–1235 (1998).
[8]CJ Harland, TD Clark, RJ Prance "Applications of Electric Potential (Displacement Current) Sensors in Human Body Electrophysiology" Proc. 3rd World Congress on Industrial Process Tomography, Banff, Canada pp. 485-490 (2003).
[9]CJ Harland, TD Clark, RJ Prance "Electric potential probes—new directions in the remote sensing of the human body" *Meas. Sci. Technol.* **13** 163–169 (2002)
[10]TD Clark, CJ Harland, RJ Prance "High resolution ambulatory electrocardiographic monitoring using wrist-mounted electric potential sensors" *Meas. Sci. Technol.* **14** 923–928 (2003)
[11]CJ Harland, TD Clark, NS Peters, MJ Everitt, PB Stiffell "A compact electric potential sensor array for the acquisition and reconstruction of the 7-lead electrocardiogram without electrical charge contact with the skin" *Physiol. Meas.* **26** 939–950 (2005)
[12]W Gebrial, R.J Prance, CJ Harland, TD Clark "Noninvasive imaging using an array of electric potential sensors" *Rev. Sci. Instrum.* **77**, 063708 (2006)

How to disentangle between luminance and cognitive load on pupil dilation measurement.

Chiara Aghemo*, Thierry Baccino**, Lauretta Chiaraviglio*, Valerio Lo Verso*, Laura Rossi * (laura.rossi@polito.it)

** Politecnico di Torino, Department of Energetics, TEBE Research Group, Torino, Italy.*
*** LUTIN-UMS-CNRS 2809, Cité des sciences et de l'industrie de la Villette, Paris, France*

Objective
Pupil dilation is usually seen as an indicator of processing demands during cognitive tasks. However, the interpretation of this parameter is often complicated by the fact that pupil dilation may be caused by different factors such as vision aspects (low-level luminance, contrast...), cognitive processes and emotion. In order to disentangle the effect of cognition and luminance on pupil dilation, an experimental investigation has been carried out where a set of subjects had to look at several patterns on a computer display in which the luminance was modified and while they had to perform a digit-span task (5 or 10 digits to memorize). Both PCA (Principal Components Analysis) and ICA (Independent Components Analysis) were carried out for identifying the main components responsible of pupil dilation (either luminance of patterns or cognitive factor).

The experiment set up
The experimental set-up was design to monitor the eye movements and pupil dilatation during the visual work and at the same time to obtain a quantitative description of the luminance behavior of the scene framed by the observer eyes. The instruments used in our experiment are:

- an Eye Tracker SMI iView X HED head-mounted monocular used with a sampling rate of 200Hz. A nine-point calibration was made for each participant. Pupil diameter was expressed in pixels, as reproduced by the eye-tracker camera on the Laptop display (resolution 1024x768);

- an ILMD (Image Luminance Measurement Device) calibrated in photopic units;

- a four channels data logger for illuminance measurements.

The experiment procedure
The test room is an obscured office, illuminated exclusively by artificial light (a lamp with two fluorescent tubes of 35 watt).
The subject doing the test is sitting in front of a laptop and is wearing the eye tracker. Behind the laptop the scene is formed by an empty room without distraction sources. In correspondence to the position of the subject’s eye an ILMD (mounting a 4,5mm lens) is positioned, “looking” at the laptop screen.

The test consists in two phases:

1) The subject is asked to look at the laptop screen on which a color is reproduced for seven seconds, while listening a set of five numbers and trying to remember the correct succession. Then a blank page is reproduced on the screen for seven seconds and the subject repeats the numbers that he/she remembers. This procedure is repeated ten times with ten different colors – with different luminance level - reproduced on the screen and ten set of five numbers. Just after the test, in the same ambient conditions, the ILMD acquires the distribution of luminance on the scene observed by the tester. The illuminances on the screen, on the desk and on the eye of the observer are acquired by the luxmeter data logger.

2) The same kind of test described in 1) is done, but with a set of ten numbers and on observation of the colored screen of 14 seconds.

Eight observers have been involved (5 female, 3 male, from 27 to 50 years old)

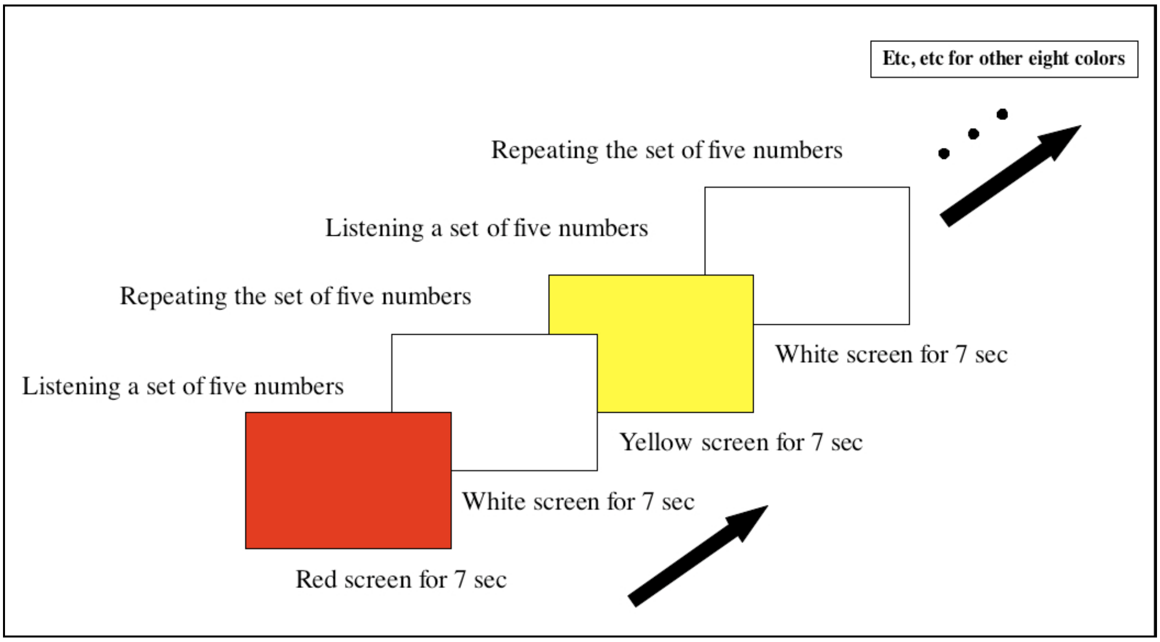


Figure 3: Scheme of the experiment.

Details of the experiment set-up, algorithms for data analysis and experimental results will be presented.

Notes

Author Index

A

Aghemo, Chiara 148
Alfonsi, A.......................................111
Amano, Kinjiro 34, 107

B

Baccino, Thierry 148
Beardsmore-Rust, S. T. 144
Berglund, B 111
Bialek, Agnieszka 72
Botteldooren, Dick 12

C

Cancedda, A 111
Cederström, Caroline 120
Chantler, M. J...................................23
Chen, Jianshe 103
Chiaraviglio, Lauretta 148
Cicchini, G. M..................................46
Conduit, Bryce 134
Conduit, Gareth..............................134
Conreen, M. 124, 127
Cornelissen, F.W..............................95
Corso, Alessio 118, 134
Crenna, Francesco 74, 111

D

Dalke, Hilary..........................118, 134
De Coensel, Bert 12
Dieleman, J.A.................................115
Drnovšek, Janko........................99, 111

E

Eitzinger, Christian 19
Elliott, David 38
Emardson, R...................................111
Emrith, K..23
Englund, Mats P................................45

F

Finkelstein, Ludwik 67
Foster, David H.........................34, 107
Francis, Susan 79

G

Geršak, Gregor..........................99, 111
Glasbey, C.A...................................115
Gonzalez, Yadira 103
Green, P. R.......................................23

H

Harland, C. J. 144
Hellström, Åke 45
Helmert, J.R. 95
Henson, Brian 24
Höglund, A 111
Hölzl, Rupert....................................84
Houix, Olivier 139

K

Kalbfleisch, M.Layne 70
Kallinen, K.....................................111
Kleinböhl, Dieter 84
Krieger, Uta 118

L

Laughlin, Z. 124, 127
Lemaitre, Guillaume.......................139
Lindberg, Siv 120
Lindström, Mikael 120

M

Marín-Franch, Iván 34
Markowitsch, Hans J. 92
Marquand, Andre 89
Marsman, J.B.C. 95
McCann, John J. 31
McGlone, Francis 83
McLachlan, Fiona 38
Miodownik, M. A. 124, 127
Misdariis, Nicolas 139
Morrone, M. C. 46
Mossberg, Frans.............................129
Mourao-Miranda, Janaina.................89

N

Nascimento, Sérgio M. C..................34
Naumann, F....................................124

O

Oldoni, Damiano 12
Overvliet, Krista...............................72

P

Pannasch, S. 95
Parraman, Carinna.............................31
Patching, Geoffrey R. 45
Pendrill, L R..................................111
Polder, G. 115
Povey, Malcolm 103
Prance, H..144
Prance, R. J. 144

R

Ravaja, N..111
Renken, R...95
Rizzi, Alessandro 31
Rossi, Giovanni B. 74, 111
Rossi, Laura 148

S

Song, Y. 115
Spence, Charles................................53
Staniloiu, Angelica 92
Stott, Laura 118
Susini, Patrick 139

T

Thumfart, Stefan 19
Tipper, Steven P.................................1
Trojan, Jörg......................................84

U

Utley, Andrea.................................103

V

van der Heijden, Gerie......72, 111, 115
Västjäll, Daniel 7
Velichkovsky, B.M. 95
Verso, Valerio Lo 148

W

Watson, P..144
Witchel, H......................................127
Wongsriruksa, S.............................124