SOUND AND COLOUR INTERACTION

The first fixation vs. the deliberate choice

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ABSTRACT

The representation of expressivity of sound and colour in functional information is still a fairly unexplored field. Alternative ways of representing functional information are necessary when providing feedback in technical environments as homes, cars, nuclear power plants, and intensive care. One possible solution could be non-verbal representation of expressivity in functional information using colour and sound signal. To determine which colours and sound signals are most suitable for an expression in a functional message, an experiment was run. Immediate first fixations of subjects and deliberate choices on 11 colours were measured and compared. Subjects rated how well each of 8 sound signals and 11 colours corresponds to each of 3 functional messages. Results of immediate first fixation and deliberate choice show that red nuances and the sound signal high pitch level, high loudness and long duration, are related to danger. Green is also in relation to danger a result which could depend on what situation participants thought of as the choice was made. While ongoing process is related to low pitch level and short duration signal. The measure of immediate first fixation is more often significant to sound than the deliberate choice is, therefore could this measure be more appropriate for the measure between sound and colour. Black and white are the colours with most first fixations and more appearing for ongoing process. On explanation of these results can be that they are more neutral colours and ongoing process can be understood as a neutral process. The results between danger and red nuances could have been influenced by a cultural convention.

Key words: colour, sound signal, danger, process, confirmation, functional information, first fixation

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1. INTRODUCTION

The present study is an attempt to investigate the expressivity of sound and colour in information conveyed in a technical environment. The choice to examine this rather unexplored but important field, is apart from own interest based on the need of options on representation of feedback information in these environments. Using sound signal- and colour representation to express functional information to the user, could be a helpful solution in home and work environments. The idea is to investigate which colours and sound signals are suitable for an expression in a functional message. Also, useful to find out is whether first fixation of eyes on object or stimuli eligible for election could provide information predicting what a person's choice will be.
Using colour and sound as complements while information is expressed could facilitate the perception of it. The stress of errors requiring prioritization could be reduced as important clues are used, whereas a lack of clues could enhance the stress in an already stressful situation (Ulfvengren, 1999).
Knowledge about the influence of these factors could provide useful information in the design field of information- providing system in for instance home products, cars, intensive care and in nuclear power plants and aircraft.

1.1 Sound and colour

In a previous experiment by Bresin (2005) where both sound and colour were included, subjects rated 12 music performances (played with saxophone, guitar, and piano) expressing different emotions using 8 colours and their 3 nuances that best fitted the particular expressive performance. Results showed for example that red was associated to anger and jealousy; and orange to contentment and shame. Results of this experiment also showed that the colour profiles differed between the instruments, as for saxophone and guitar performances the dark versions of colours red, orange, blue and violet received higher average preferences, while the piano performances the light versions of them get higher rates. Bresin (2005) stated that the instruments provide acoustic clues that are important in the communication of emotions. So, the explanation for the results could lie on the acoustic clues expressed by the instruments which evoke different colour association. These results gave indications towards a hypothesis about a relation between sounds and colour.

Further studies have reported that clues both can be visual and acoustic. It was demonstrated that auditory and visual interaction speeds stimuli discrimination capabilities (Marks, 1987) and that the surface colour of an object affects its recognition (Tanaka et al, 2001). This could mean that the process of identification of functional information could be increased by using a system in which the expressivity of functional information was represented by sound (auditory) and colour (visual). Therefore this could be useful in different environments as it is stated by Norman (2002) that important clues in many environments are invisible, indicating the poor design of these things. In agreement to Norman's statement, Ulfvengren (1999) considered the design of many safety critical human- machine systems to be poor in aspects of discrimination between signals. The type of sound signal is assumed to be indicative of how quickly a response is required (Ulfvengren, 1999), and as Norman (2002:104) stated:

> Just as the presence of sound can serve a useful role in providing feedback
> about events, the absence of sound can lead to the same kinds of difficulties

> we have already encountered from a lack of feedback. The absence of sound can mean an absence of information…

Expressing functional information by representing it by both auditory and visual clues could facilitate the discrimination between different types of information.
On the following sections background information about sound and colour is presented.

Sound

Gaver and Smith (1990) reported that sound signals can give *confirming* information by giving the user feedback about the occurrence of an event. *Process sound* providing information about an ongoing *process* in the system, and *navigation sound* which navigates or guides the user.
Starting from this theory, two functional information messages have been elected for the current experiment as they are assumed to be relevant in technical environments. The two functional messages are ongoing process and confirmation. The third functional message is danger as it is present in technical environments and therefore relevant.
In a previous experiment, Malki and Shatri (2006) examined the influence of sound signal structure on the perception of the function of a technical product. Results which were reported showed an interaction between a sound structure combination signalling *danger*. The sound structure was: high loudness, high pitch level and long duration. Short duration of a sound signal was in interaction to *wrong usage,* while the function *technical error* was in interaction to low pitch level and short duration. So, non dangerous information was assumed to be best expressed by short duration and low pitch level combinations in sound.
The results above and the statement that loudness has a large effect in being perceived as urgent (Ulfvengren, 1999), indicate that sound with high loudness expresses information perceived as urgent. Important to be mentioned is that separate properties of the tonal hierarchy can be additive in achieving perceived association (Lindström, 2004), as could be the case with the results reported by Malki and Shatri (2006).

Ulfvengren (1999) considered that by using natural signals in working environments could irritation and confusion be contradicted and provide information available in no other way. It was stated by Norman (2002) that sound can tell us whether things are working properly, or that they need maintenance or repair, it can even prevent accidents. One of the virtues of sound is the fact that it can be detected even when attention is applied elsewhere. Therefore should sound express something about the actions that are taking place i.e. ongoing process, and actions that matter to the user that otherwise would not be visible, for example in important and dangerous situations. When sound is used properly it can give valuable feedback to confirm that operations are completed. The user will be assured that for example the button has been pressed, as Norman (2002:103) puts it:

> Real and natural sound is as essential as visual information because sound tells us about things we can’t see, and it does so while eyes are occupied elsewhere.

Colours

In agreement to the results reported by Bresin (2005) that red was associated to anger and jealousy; and that orange was associated to contentment and shame, other studies reported similar associations.
Results reported by Ballast (2002) and Mahnke (1996) showed that orange was perceived as distressing and upsetting, yellow as cheerful, purple as dignified. Red had both positive and negative impressions such as active, strong, and passionate, but also aggressive, bloody, raging and intense. Green had a retiring and relaxing effect, and gave impressions such as quietness, naturalness, and conversely tiredness and guilt (Davey 1998, Linton 1999).

There exist different colour systems. The Munsell *colour wheel* system (see Figure1) was used as a stimulus in several of the above mentioned studies, and was considered to be relevant to the current experiment.
Berlin and Kay (1969) identified following basic color terms in a study: *black, grey, white, pink, red, orange, yellow, green, blue, purple, and brown*. Using many nuances of each colour in an experiment would be complicated to analyse, therefore the design of the wheel, containing 11 commonly used colours will be used in the current experiment.

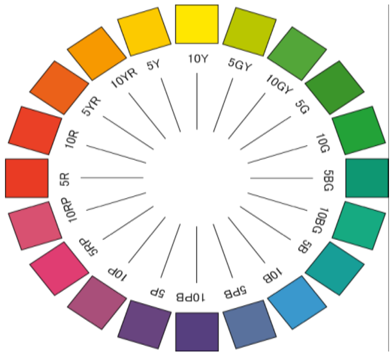


Figure1. The colour wheel

Eye movements

Results reported by Atkinson et al (1993) indicate that the primary means for directing our attention to objects of interest are eye movements, and fixations being on the more informative parts of a scene. In this study it is stated that we select stimuli for further processing while ignoring other stimuli, which also happens with acoustic stimuli, as was the case in Bresin (2005) study.
Based on information in the two previous sections there is a possibility that by letting sound and colour represent the expression of functional information it could make the discrimination between functional information easier. As attention is directed by acoustic clues to suitable colours (Bresin, 2005), it is possible that after having listened to a sound fixations land on the most suitable colour. As Christianson and Engelberg (2000) report, the recognition and identification of stimuli indicative of threatening situations could be partly based on unconsciously controlled processes. The same could be the case with first fixations which are immediate reactions to stimuli.

1.3 The purpose of the study

As we live in a rather technical world, technical objects always surround and inform us. By having alternative ways of representing functional information the perception of it would be easier. There are many advantages with studying within this field, therefore the purpose is to find out by which sounds and colours functional information (danger, ongoing process, confirmation) can be represented.
This study aims to find sound and colour combinations to express functional information, which could be useful for the understanding of what a system does.

1.4 Hypothesis

Based on reported results in previous sections the assumptions were made that:

H_1. There will be differences between the first fixated colour, which is an immediate reaction to the stimulus and the chosen colours which is a considerated reaction to the stimulus.

H_2. Red colour and the sound signal with high pitch level, high loudness and long duration will relate to the functional message, *danger*.

This hypothesis is based on reported results by Malki and Shatri (2006) since this sound signal structure is related to danger, and loudness has a large effect in being perceived as urgent as stated by Ulfvengren (1999). Red is shown to be aggressive and angry as reported earlier (Ballast, 2002; Mahnke, 1996; Bresin 2005).

H_3. The functional messages, ongoing process and confirmation will be related to sound signals with low pitch level and short duration, and to green.

Based on results by Malki and Shatri (2006) were low pitch level and short duration related to non danger functions of technical objects. Green is reported as associated to retiring and natural (Davey 1998, Linton 1999).

2. METHOD

An experiment was designed in which it was tested which colours and sound signals were most suitable for expressions in 3 functional messages, danger; ongoing process and confirmation. For the conduction of the experiment an eye tracker was used to gather data of first fixations on the colours which were eligible for election.

2.1 Participants

Ten men and ten women with a mean age of 25.5 years, all Swedish students at Lund University participated in this study independent of education type. All of them met the standard visual acuity criteria to execute the experiment. Three participants wore eye lenses but this was not a problem to calibrate the eye tracker to. The left eye of the participants was used in the experiment.
All participants were informed that participation in this experiment was confidential and data would be used in statistic measures for this experiment. The participants gave their consent in writing for usage of the data in the current study and other relevant studies. The ethical guidelines of Humanistlaboratoriet and Lund University were followed during this experiment.

2.1 Equipment

Equipment at Humanisttlaboratoriet, at Lund University was utilized. The lab was equipped with the stationary eye-tracker SMI iView X Hi-speed 240 Hz (see Figure 2), capable of high spatial resolution. Eye movements were calibrated using a 13 point calibration accuracy test before the experiment. Participants were seated by the eye tracker in front of the stimulus monitor display with a distance of 70 cm.
The experiment and stimuli were prepared in and presented with E-Prime v1.2 on a 17“ LCD Hitachi display. The resolution and size of colour image stimuli was 800x600, 16 bit images. Eye coordinates were recorded with the program iViewX, as the eye tracker was operating with. The eye movement data from iViewX was converted into text files and read with BeGaze v1.2.75.

Ear phones were used, AKG K-66, for better counteraction of outside environmental noise, but also to give all subjects the same conditions.
The sound signals were produced with the help of a *mixerbord Behringer Eurorack MX802* and for duration manipulation of the sound signals was conducted with Audacity 1.3 Beta.
Programs which have been used for the preparation of colour stimuli were Adobe Photoshop7.0 and GIMP 2.2. The program SPSS was used for statistical measures.
Before using the equipment some tests were carried out in the laboratory to make sure the experiment would run without problems.

Figure 2. The stationary eye tracker

2.3 Procedure and Design

The psycholinguistics method of visual world paradigm (van Gompel et al 2007) was an inspiration for the design of the following experiment.
First an introduction to the equipment was done, after which written instructions about the experiment and information about the ethical guidelines of Humanist Laboratory at Lund University was given (see Appendix I). Participants were seated comfortable in front of the stimuli display, by the eye tracker and the eye tracker was calibrated. After one training session participants were asked if the procedure was understood.
Experimental conditions, both sound and colour, were presented in randomized order for all participants. After sound presentation and prior to colour presentation, participants were asked to fixate their eyes on the fixation point in the middle of the screen, so the starting point of fixations would be the same for all conditions.

Experimental Conditions
One experiment cycle consisted of one set of 8 randomized sound signals (see Table 1), one colour image condition (see Figure 4) was presented each time a signal was played, and 3 rating scales for functional messages repeated after each combination. In the beginning of a new experiment cycle which consisted of the same conditions but another set of randomized sound signals and another colour image condition, an alarm signal was played. By starting a set or

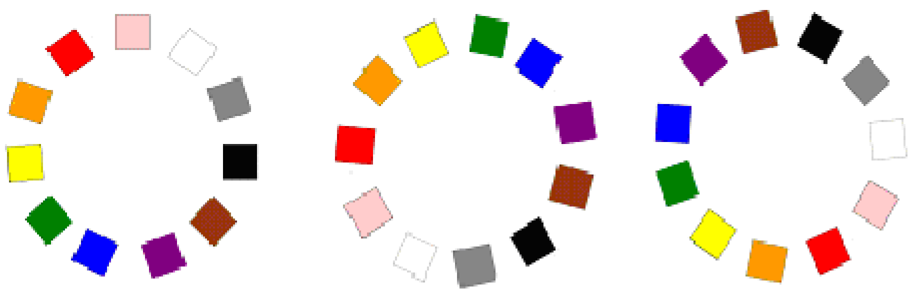
cycle with playing the same alarm signal, it was assumed that participants would understand that a change had been made, and the learning of the colour positions would be contradicted. This was also assumed to give better credibility because the chance that eyes might move in the same direction each time the colour image appeared was counteracted by these changes.

Table 1. Example of 3 sets of sound conditions.

Sound conditions	HHK	HHL	LHK	LHL	HLL	HLK	LHK	LLL
Sound conditions	HHL	LHK	HHK	HLK	LHL	HLL	LLL	LHK
Sound conditions	HLK	LHK	LHL	HHL	LLL	HHK	LHK	HLL

Basic combinations of sound signals originally in Swedish were: the first letter, high/low pitch level with a variation of high/low loudness i.e. the second letter, and short and long duration i.e. third letter (see also Table 3, Appendix II). The sound signals were randomised in three sets for three sets of colour image conditions, in E-Prime.

Participants listened to one of the 8 sound signals for 3500 ms while they fixated eyes on the fixation point for 3500 ms after which one colour image was presented. After participants clicked on/ chose a colour, they were asked to ascribe the combination a meaning by rating how suitable the combination was to danger, to ongoing process and to confirmation. The rating scale was a scale of 0-7, where 0 i.e. not at all suitable and 7, very suitable. First fixations on colours are immediate reactions/behaviour, while the choice or the click on a colour is a considerated or deliberat behaviour.



a) The original 0º b)120º c) 240º

Figure 4. Colour conditions.

At the end of the experiment participants gave their consent for usage of data in the current study and other relevant studies, in writing and received a reward for their participations (see Appendix I). The time process for the experiment was approximately 15-20 minutes, including calibration.

The intern validity in laboratory experiments is good, as it is in the current experiment. As all colours had the same chance of being fixated by the rotation of the stimuli, was the learning effect prevented.

2.5 Data analysis

As mentioned in the equipment section eye coordinates were recorded with the help of the iViewX program, and were later converted for analysis in BeGaze. In BeGaze, areas of interest, AOI, were marked on each colour of the 3 conditions (see Figure 4). Data from BeGaze was transformed to Microsoft Excel and prepared for the statistical analysis in SPSS, as was the rating click data coordinates from E-Prime.

Taking the functional message as a starting point the comparisons of sound and colour were analysed. How high the combinations (sound-colour) were rated on the scale for the functional messages, decided what colour and what signal was significant or in relation to a specific functional message.

3. RESULTS

Choice vs. First Fixation
A summary of first fixated and chosen colours by all participants, after the sound signals were played, in all conditions (see Table 2, Appendix III) show that the times that the first fixation lands on the colour which is deliberately chosen, is higher than if it would be a random coincidence (see Figure 5). This lies therefore on 21.5% level instead of 9% level (see Figures 6, 7 and 8 in Appendix III for comparison). 21,5% is higher than the expected if random (9%) level, and though it is low it still indicates that there could be a relation between the somehow instinctive and immediate and the conscious choice. No gender differences were found (see Figure 10a & b, Appendix III).

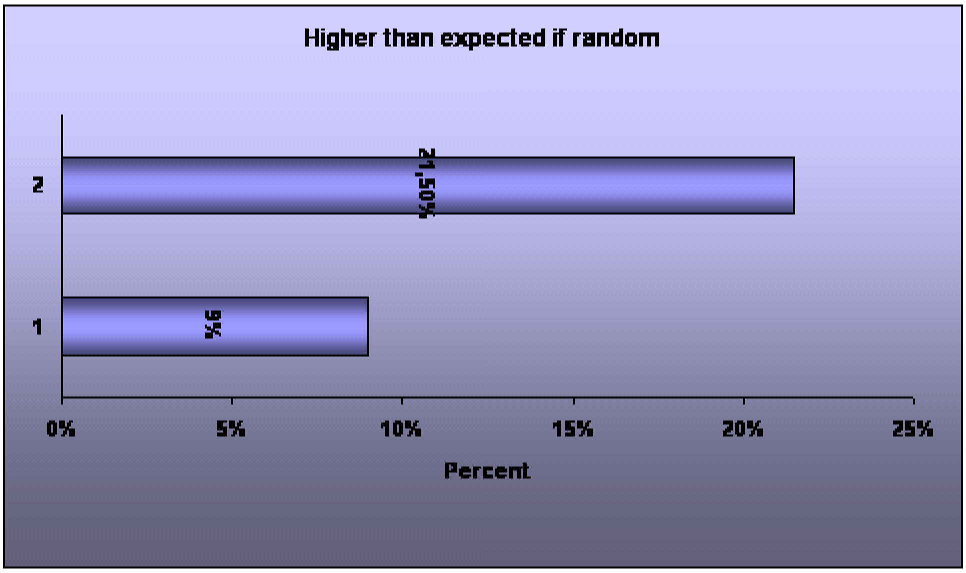


Figure 5. Shows 1) the expected if random level, and 2) times the fist fixation landed on the same colour as was deliberately chosen.

Kappa Analysis
Measure of agreement Kappa analysis shows no significant agreement between chosen colours and first fixated colours (see Table 4, Appendix II).

ANOVA, Danger

Anova measures were conducted, (between subjects design) taking danger as a starting point. Results show a significant interaction (see Table 5, Appendix II) between danger and sound signal at .05% level; F (7,395) = 21,858; p < .05. Also, between danger and chosen colour there is a significant interaction at .05% level F (10,395) = 1,626; p < .05% (see Table5, AppendixII). There is no significant interaction between sound and chosen colour F (67,395) = 1,075; p > .05% (see Table5, AppendixII).

Further significant interaction is found between danger and first fixated colour at .05% level; F (12,384) = 2,809; p < .05% (see Table 6b, Appendix II). Between sound and first fixation no between factors interaction was found F (77,384) = 1,035; p > .05% (see Table 6b, Appendix II). There is an interaction between the first fixated colour and the chosen colour at .05% level; F (102,355) = 1,450; p < .05% (Table 6a, AppendixII), supporting Figure 5. It was hypothesized that there would be differences between the deliberate chosen colour and the fixated colour, but these results do not indicate that it has to be like that.

Post Hoc Tests (Tukey HSD), multiple comparisons, were conducted for all the above mentioned factors showing results presented as follows.

Sound

The effect between the "high loudness" group of sound signals and danger are significant at .05% level (Figure 6). Most significant of these signals is HHL with a mean of 4,9 (see Table 7, AppendixII). These results confirm the second hypothesis that the sound signal with high pitch level, high loudness and long duration would be in relation to danger. Specially loudness is shown to have important effect on being in relation to danger as all 4 signals with high loudness (Figure 9) are significant.

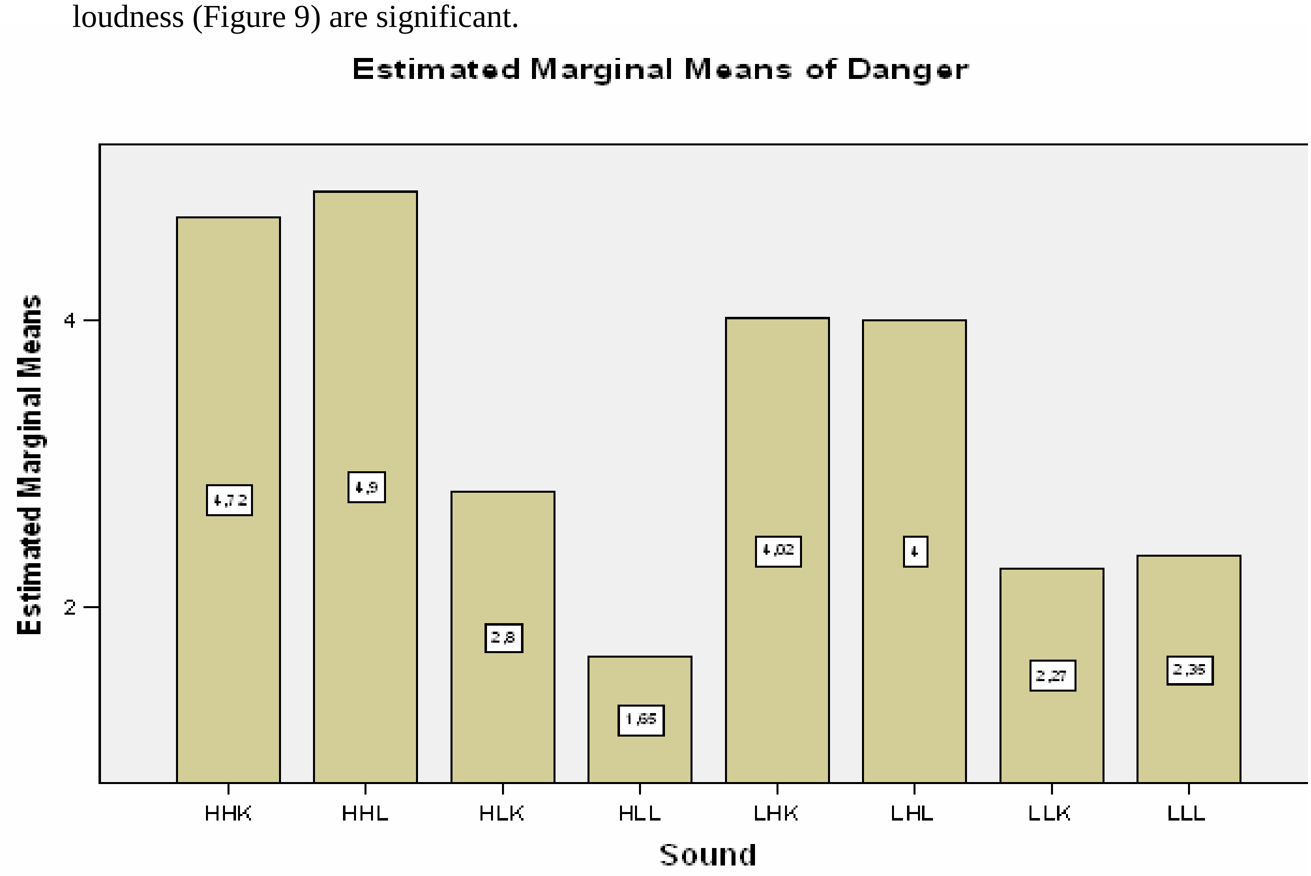


Figure 9. Sound signals with high loudness have an overall higher effect, as does the hypothesized sound-signal HHL.

Chosen colour

Results of the Post Hoc Tests show a significant relation at .05% level between danger and the chosen colour *orange* (see Figure 11), with a mean of 4,388 followed by *green* with a mean value of 4,306. The results of this analysis do not confirm the second hypothesis that red would be the colour in relation to danger, but still orange is a colour of the red nuances.

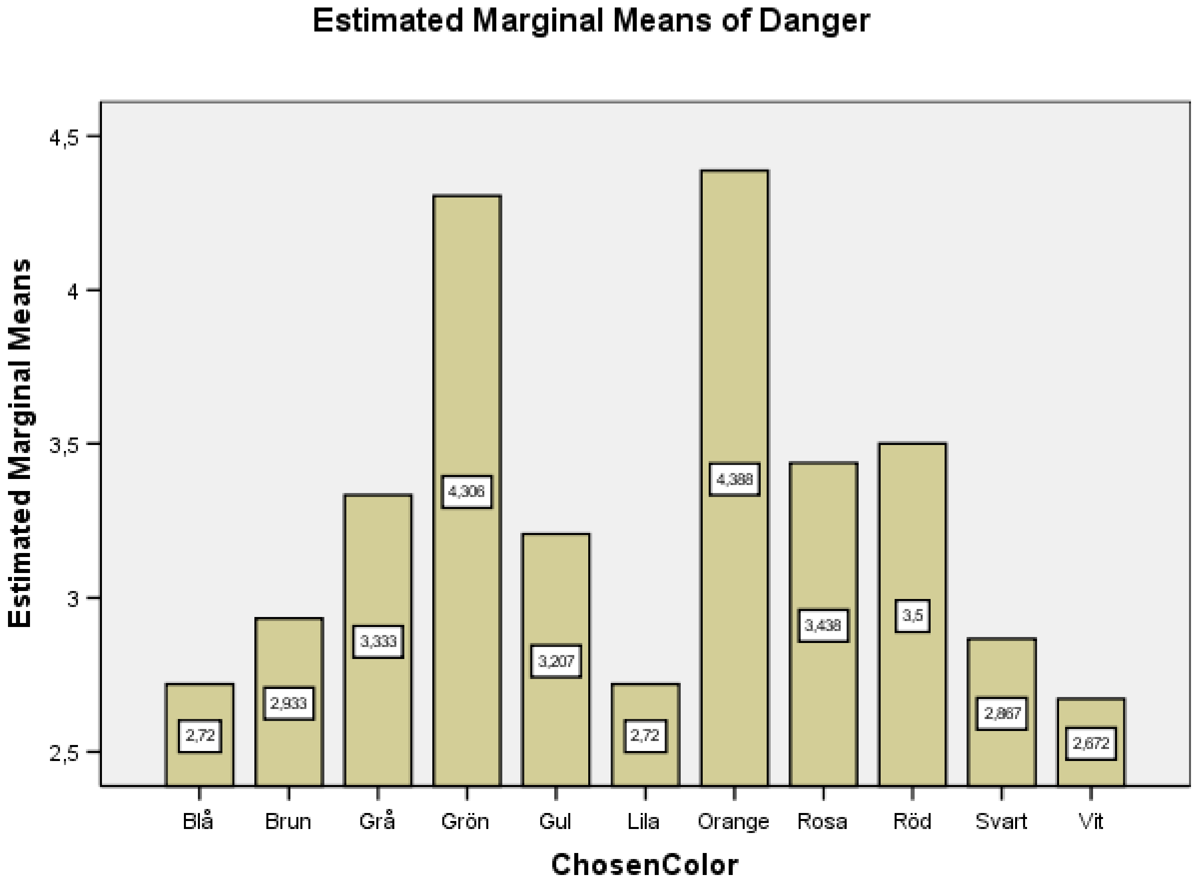


Figure 11. Figure showing that the colours orange and green have the largest contrast of all colours.

First fixated colour

The Post Hoc Test on the functional message danger and first fixated colour (see Figure 12) shows interesting results of an interaction between danger and *orange* with a mean value of 3,962, followed by *red* with a mean value of 3,926.

It is hypothesized that the ratings of danger would show result connecting red to danger. Interesting results show that the red nuance, orange is both the considerated, chosen and immediate first fixated colour. Red follows after orange also being an area of interest where the first fixations have landed on.

Confirming hypothesis 1 results show that the values for green in the two cases differ, as green in contrast to chosen colour (see Figure 11) has low values for being first fixated.

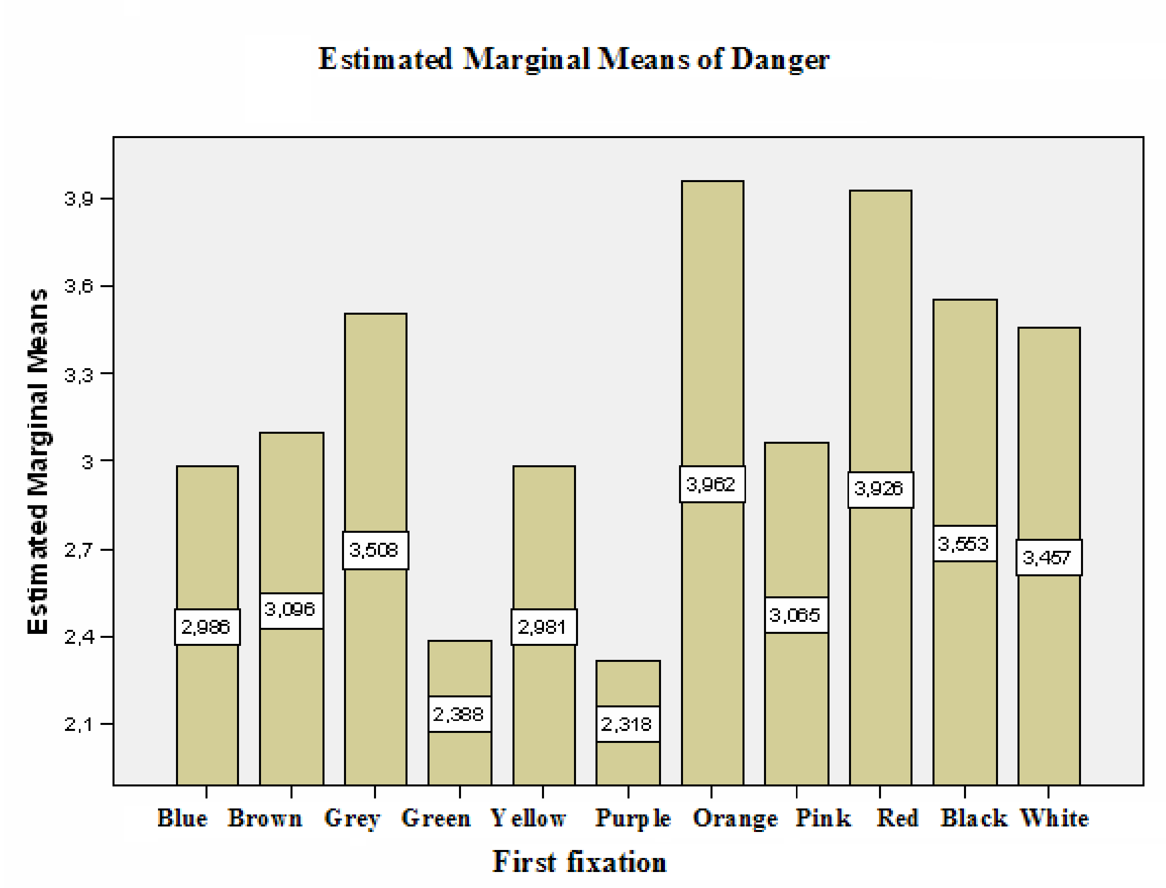


Figure 12. Orange and red in largest contrast to other colours.

ANOVA, Ongoing process
Anova measures were conducted for this functional message rating scale and shows significant interaction between ongoing process and sound signal at .05% level; *F* (7,395) = 2,449; *p* < .05% (see Table8, Appendix II). Significant effect are also found between ongoing process and first fixation at .05% level; *F* (11,357) = 1,955; *p* < .05%; and a between factors interaction of first fixation and chosen colour, at .05% level *F* (101,357) = 1,955; *p* < .05% (see Table9, Appendix II). The chosen colour it self is not significantly in interaction with ongoing process, *F* (10,395) = ,922; *p* > .05% (Table8, Appendix II).

Sound
Further the Post Hoc Tests (Tukey HSD) shows HHK with a mean value of 4.183 and LHL with a mean value of 4.167 in contrast of the signals (see Table 10, Appendix II). In hypothesis 3 it was assumed that sound signal with low pitch level and/or short duration would be in relation to ongoing process. These results confirm that short duration and low pitch level are significantly in interaction to ongoing process (see Figure 13).

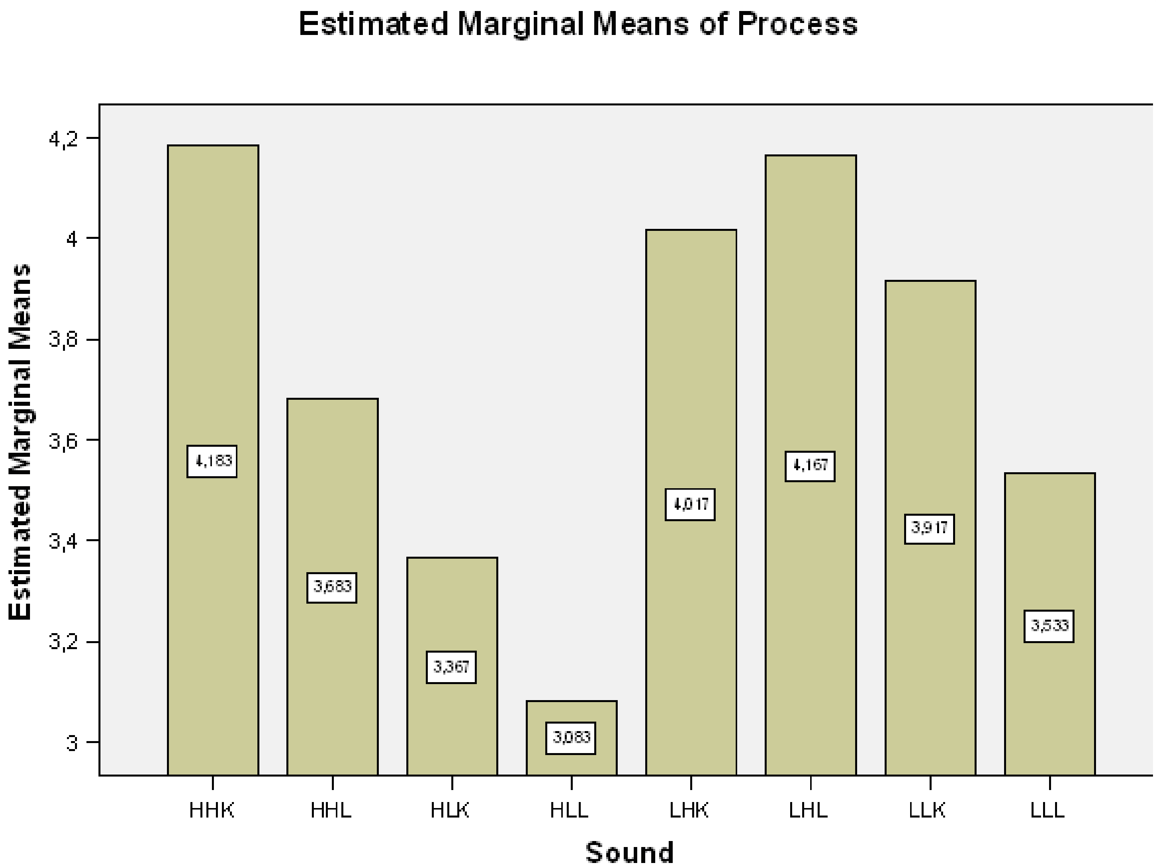


Figure 13. The largest contrast of the sound signal is HHK followed by LHL.

First fixation

Results of the Post Hoc Tests (Tukey HSD) show a significant relation between ongoing process and *black* (see Figure 14), with a mean of 4,335 followed by *white* with a mean value of 4,228. The results of this analysis do not confirm the third hypothesis that ongoing process would be in relation to green, but are still unexpected and interesting.

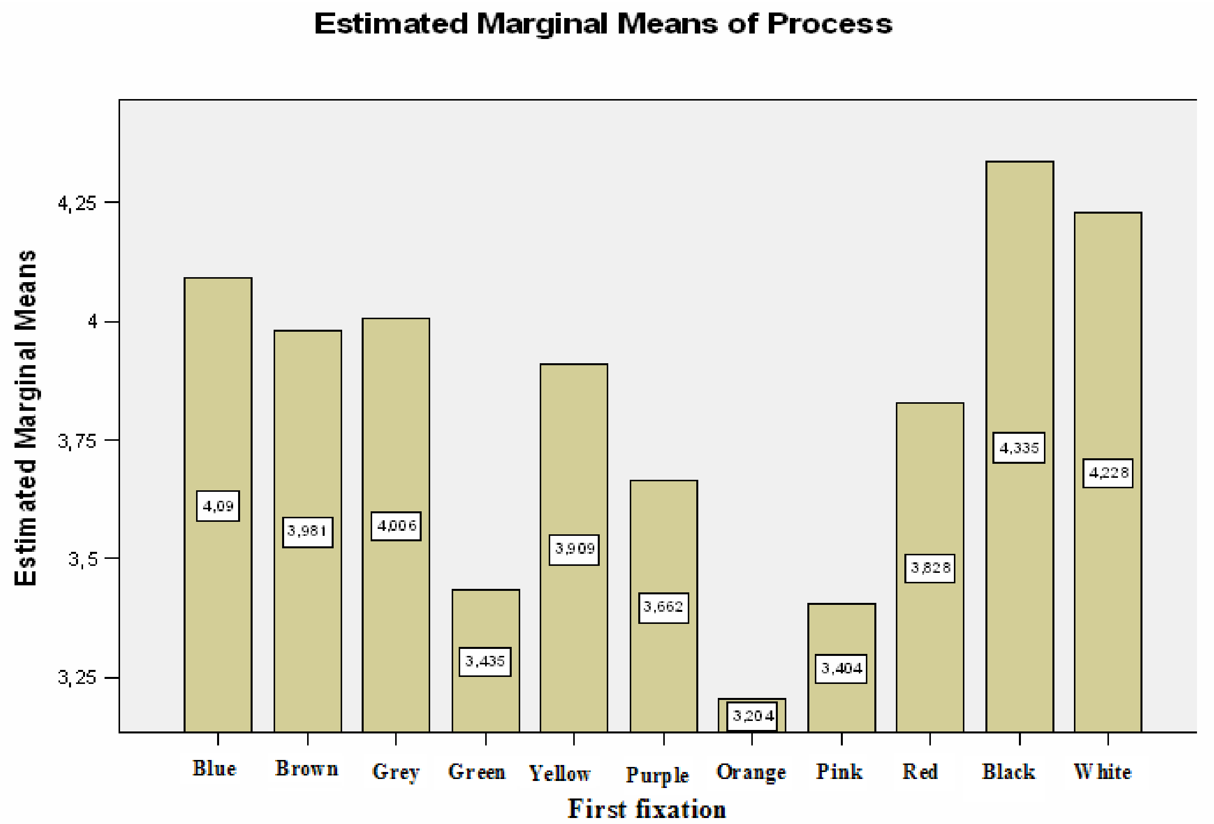


Figure 14. Black and white in relation to ongoing process.

Confirmation
ANOVA measures were conducted, (between subjects design) for this functional message rating scale and shows results indicating that there is no significance between confirmation and: chosen colour. *F* (10,395) = ,902; *p* > .05%; likewise no significance to sound signal *F* (10,395) = ,726; *p* > .05%; and no between factors interaction (sound-chosen colour) *F* (67,395) = ,868; *p* > .05% (see Table10a, Appendix II). Results do not confirm a relation between confirmation and first fixation *F* (11,468) = 1,249; *p* > .05% (see Table10b, AppendixII).

4. DISCUSSION

The representation of expressivity through sound and colour in functional information is still a fairly unexplored area therefore the hopes of the present study are to contribute to it. This study is performed to determine which colours and sound signals are most suitable for expressing functional information. By using non-verbal representation of expressivity in functional information, using colour and sound signal can a lot of stress and misunderstanding in technical environments be prevented.

The three hypothesis of this study have more or less been confirmed by the results of the current study. We have significant interactions between the first fixated colours and sound signals, for danger and ongoing process. While chosen colour is significant to sound, only for danger. These results indicate that the times the first fixated colour and the chosen one match are higher than if it would have been a random coincidence. The gathered results show the first fixated colours being significantly in interaction with the two functional messages, indicating that the first fixation measures could be a better or more appropriate measure for the relation between sound and colour, than clicked or chosen colours is. This also confirms the first hypothesis about the difference between an immediate and a considerated or deliberate choice. So, could it be that the immediate first fixation is a better measure than a considerated choice on stimulus? The first fixation might after all be able to provide information predicting a person's choice. To find an answer to this question more studies have to be performed in the future.

Loudness or in this case high loudness is in relation to danger, as is the hypothesized sound signal HHL, but not red as assumed in the first hypothesis. The assumption that red would be in relation to danger has been falsified although orange is a red nuance. Results show interesting facts since significantly many first fixations landed on red and orange. This means that red nuances of colours, red and orange, can be used to represent and express danger and it would probably still be interpreted in the right way.

One explanation of why the results for this functional message are like this, could be based on a cultural convention. According to previous studies red is associated to anger and jealousy and orange to shame (Bresin, 2005), in many cases red is a standard colour used for warning people and signalling that a situation is dangerous. Another explanation of the results is that we are just used of having red alarms, ambulances etc. One should maybe follow these cultural principles in aspects of allowing the use of a colour to represent danger.

Another interesting result is the green colour being in relation to danger. Depending on what situation participants thought of when the colour choice was made it must have had an effect on their judgment. The meaning of these results can be studied further to have enough background information about what a participant thinks of. Since the first fixation could be a more suitable measure for this relation and is an immediate response it can be as assumed to be a more true connection of sound and colour. Also fixations being on the more informative parts of stimuli (Atkinson et. Al. 1993) strengthens this idea.

Ongoing process was hypothesized to be related to low pitch level and short duration, results show that both high and low pitch level, and both short an long duration are in interaction with the functional message (third hypothesis is still confirmed by these results). One explanation for these results could be that there were not enough many or enough different sound signals eligible for election to make a brighter discrimination between the signals possible. The more appearing colours for ongoing process, black and white, depend on the individuals who participated as they maybe did find these more neutral colours to be suitable for the functional message as ongoing process can be understood as a neutral process.

Confirmation was expected to be in association to green and similar sound signal type as was hypothesized to relate to ongoing process, but no significant effects were found meaning the third hypothesis is partly falsified. The new contribution of the present study is that these associations were obtained using eye movements, colours and sound signals.

It is interesting that some results of the present study fit with results reported by previous studies. Having two different sound signals with the same structure, in two different experiments resulting the same way, is very interesting and gives indications of special connection between danger and that special sound signal structure of high pitch level, high loudness and long duration. Loudness (Ulfvengren, 1999) was pointed out as a parameter important for expressing danger, as has been shown in the present study since a group of sound signals with high loudness were significant to danger. This sound signal might have the right balance to be detected even when attention is applied elsewhere, as Norman (2002) was worrying about. Red nuances have been shown to have the effect of expressing danger with that particular sound signal, as it might have the capacity to fill an absence of information as is mentioned earlier (Norman, 2002). They are also normally associated to anger (Bresin, 2005) and used in environments to signal danger, so the cultural principles are showing even in the population participating in the present study.

There are many advantages with exploring this field, as is mentioned above, since technical objects always are surrounding us, at home and at work and the affection of them has been reported to be large. The use of sound and colour is important since it can be used in much more communication than it is used for today, especially in artificial devices where it should be as useful as in the real world. One quality of sound is that it can be detected even when attention is applied elsewhere (Norman, 2002), and colour in different nuances can give something a pop-out effect. It is important that producers of information providing systems have knowledge to control cues effectively to achieve different expressive performances.
To have more correct and deeper information for different functional messages to be used in different environments, it is important to perform more studies using more sound signals and colours in different nuances. From the current study it can not be decided that specific sound and colour are the most appropriate to be used for expressing functional information, though significant interactions are found. There are still many questions to be answered as I am sure that there exist other sound signal structures and colours, which have a probably as strong effect and connection to functional message and information as the above mentioned have to danger, therefore have more studies to be performed.

Further ahead I am interested in investigating in the area of sound influence and eye movements. With the knowledge about what we respond to in sound, can the construction of sounds to be used in technical and safety critical environments go one step closer to apply the right sound for the right function. The associations reported in this study could also be interesting for studies in the area of synaesthesia.
I find the results of this experiment very interesting and hope that they will be a contribution to the area. I believe that results would be more interesting if the number of sound stimuli would have been higher, also the number of subjects can contribute to other results. With the right time and resources available it is possible to do some further investigation in the field of color- sound, even to include emotion. There exist several studies performed by using the Munsell colour system and other colour systems, which report results that confirm a correlation between colour and emotional associations, and colour brightness with different emotional associations (Bresin, 2005; Boyatzis &Varghese, 1994; Hemphill, 1996).
The performance of an experiment examining colour brightness, sound structure and emotions would be interesting and there is a large possibility that it would show results indicative of an interaction between dark colours and negative sounds and negative emotions; and vice versa. To be able to perform this experiment it is necessary to have resources to produce different sound signals and run a number of experiments.

6. ACKNOWLEDGMENTS

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Appendix I

Auditiva signalers interaktion till färg

Hej,

Mitt namn är Laurela och detta experiment är en del av min magisteruppsats i Kognitionsvetenskap. Som det framgår av titeln, är syftet att undersöka sambandet mellan ljudsignal och färg, och jämföra med vad man tidigare vet om ljudsignals och färg uppfattning. I denna undersökning kommer jag att undersöka frågan med hjälp av en eye tracker som mäter dina ögonrörelser när du ska välja färg.
Det är även intressant för mig att få reda på till vilket syfte som du anser att en viss kombination av ljudsignal och färg skulle kunna användas.

I en eye tracking studie använder vi alltid kalibreringspunkter, som du också ska få titta på, för bästa reglering av eye trackern till dina ögon.
Du kommer att hålla ögonen fixerade på en punkt i skärmen och lyssna på en ljudsignal. När ljudsignalen har spelats färdig, ska du få titta på färger och välja den färg som du anser passar bäst till ljudsignalen.

För att finna till vilket syfte som en ljudsignal och en färg kan användas till, ska du gradera din uppfattning på en skala från 0 till 7, där 0 står för inte alls passande och 7 mycket passande. Till exempel till vilken grad som en ljudsignal och en färg berättar för dig att något är farligt, att en process pågår eller att de kanske bekräftar att någonting har hänt.

- Med någonting som är farligt menas, exempelvis en varning som säger att maten har värmts för länge, att något är sönder, eller ännu värre att något farligt verkligen har inträffat.
- Ett ljud och en färg som beskriver att en process pågår, kan till exempel vara att din dator uppdaterar något, eller att mikron hemma hos dig visar att maten är under uppvärmning.
- Att en ljud- och färgkombination bekräftar något kan innebära att de t.ex. används för att visa för dig att ditt sms har skickats, uppdateringen är klar eller maten i mikron är färdig.

Om du har några frågor och undrar över någonting, så går det bra att ställa frågorna innan experimentet startar så finns mer tid att förklara allt för dig.

Tack för ditt deltagande och lycka till!!

Med vänlig hälsning, Laurela.

LUND UNIVERSITET
Humanistlaboratoriet, SOL-center
Mars 2007

Deltagande i projektet ”Auditiva signalers interaktion till färg”

Studiens syfte är att undersöka interaktionen mellan ljudsignal och färg, och jämföra med vad man tidigare vet om ljudsignals- och färguppfattning. Denna studie har inte blivit granskad av regionala etikprövingsnämnden, då Humanistlaboratoriets etiska regler har bedömts vara tillräckliga.

Samtyckesdokument

- Jag informerades innan experimentet om att jag kunde avbryta experimentet närhelst jag ville.
- Jag vet att jag kan ångra mitt deltagande och få datan förstörd så länge datan inte hunnit användas i en presentation eller publikation.
- Jag vet att om datan har blivit använd för presentation eller publikation så klassas den som en offentlig handling, som kan begäras ut av någon om särskild anledning föreligger.
- Jag vet att forskarna har tystnadsplikt och inte berättar om just mitt resultat för någon, förutom i anonym form.
- Jag har förstått i vilken form datan existerar, vad som kan vara identifierande särdrag i datan och vilka risker för kränkning som föreligger för denna typ av data.
- Jag godkänner att du använder datan för presentationer vid kurser, seminarier och andra akademiska sammanhang.
- Jag har ställt upp av egen vilja utan att ha känt mig tvingad - socialt eller på annat sätt.
- Jag känner mig nöjd med den information jag har fått kring experimentet och har fått tillfredsställande svar på mina frågor.

Lund den ___________________________ 2007

____
Läsaren

____
Ev vårdnadshavare

____
Den som förklarat innehållet i denna samtyckesblankett

Det ligger i forskarsamhällets intresse att många kan få del av den data vi spelat in. Vid Humanistlaboratoriet i Lund förbereder vi för delning av forskningsdata via öppna databaser. Om du vill ge ditt tillstånd för oss att dela ut dina data vill vi ha din underskrift även för detta. Om du inte vill att dina data delas ut, så behåller vi data endast inom vår egen forskargrupp.

- Det som läggs ut i databasen är koordinater för hur dina händer har rört dig över bilder och texter, en film på dina händer, samt din röst. Dessutom ingår bakgrundsinformation om dig, t.ex. din ålder och din läsvana.
- De som registrerar sig i databasen kan ladda ner all denna data och analysera den hemma på sätt som vi kanske inte räknat med.
- Medgivandet till datadelning kan återkallas, men att detta inte nödvändigtvis stoppar data som redan har blivit delad till andra människor.

- Jag kan överblicka den totala information som delas och riskerna att denna kan härledas till mig.
- Jag har fått svar på mina frågor rörande datadelning och anser mig överblicka riskerna väl.
- Jag ger mitt godkännade att mina data delas ut, utan tvång av något slag.

Lund den ____________________________ 2007

____
Läsaren

____
Ev vårdnadshavare

____
Den som förklarat innehållet i denna samtyckesblankett

Appendix II

Table 3

Sound conditions	HHK	HHL	LHK	LHL	HLL	HLK	LHK	LLL
Sound conditions	HHL	LHK	HHK	HLK	LHL	HLL	LLL	LHK
Sound conditions	HLK	LHK	LHL	HHL	LLL	HHK	LHK	HLL

Letter combinations
H = High pitch level/ loudness
K = Short duration
L = Low pitch level/loudness/long duration

The position of letters
First letter = Pitch level
Second letter = Loudness
Third letter = Duration

Table 4.

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	-.008	.015	-.534	.593
N of Valid Cases		429			

a. Not assuming the null hypothesis.
b. Using the asymptotic standard error assuming the null hypothesis.

Danger

Table5.

Tests of Between-Subjects Effects

Dependent Variable: Function_Danger

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	877.467(a)	84	10.446	3.793	.000
Intercept	3404.831	1	3404.831	1236.290	.000
ChosenColour	**44.768**	**10**	**4.477**	**1.626**	**.097**
Sound	**421.387**	**7**	**60.198**	**21.858**	**.000**
ChosenColour * Sound	198.324	67	2.960	1.075	.333
Error	1087.858	395	2.754		
Total	7312.000	480			
Corrected Total	1965.325	479			

a R Squared = .446 (Adjusted R Squared = .329)

Table 6a.

Tests of Between-Subjects Effects

Dependent Variable: Function_Danger

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	763,706(a)	124	6,159	1,820	,000
Intercept	2439,618	1	2439,618	720,748	,000
FirstFixation	76,882	12	6,407	1,893	,034
Chosen_colour	108,788	10	10,879	3,214	,001
FirstFixation * Chosen_colour	500,664	102	4,908	1,450	,007
Error	1201,619	355	3,385		
Total	7312,000	480			
Corrected Total	1965,325	479			

a R Squared = ,389 (Adjusted R Squared = ,175)

Table 6b.

Tests of Between-Subjects Effects

Dependent Variable: Danger

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	941,731(a)	95	9,913	3,719	,000
Intercept	3951,253	1	3951,253	1482,308	,000
Sound	426,671	7	60,953	22,866	,000
@1stFixation	82,354	11	7,487	2,809	,002
Sound * @1stFixation	212,499	77	2,760	1,035	,407
Error	1023,594	384	2,666		
Total	7312,000	480			
Corrected Total	1965,325	479			

a R Squared = ,479 (Adjusted R Squared = ,350)

Table 7.

Function_Danger
Tukey HSD

Sound	N	Subset		
		1	2	3
HLL	60	1,65		
LLK	60	2,27	2,27	
LLL	60	2,35	2,35	
HLK	60		2,80	
LHL	60			4,00
LHK	60			4,02
HHK	60			4,72
HHL	60			**4,90**
Sig.		,291	,647	**,062**

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = 2,754.
a Uses Harmonic Mean Sample Size = 60,000.
b Alpha = ,05.

Ongoing Process

Table8.

Tests of Between-Subjects Effects

Dependent Variable: Funktion_Process

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	235,364(a)	84	2,802	,910	,695
Intercept	4544,916	1	4544,916	1476,208	,000
Sound	52,773	7	7,539	2,449	,018
Chosen_colour	28,392	10	2,839	,922	,513
Sound * Chosen_colour	135,971	67	2,029	,659	,981
Error	1216,117	395	3,079		
Total	8179,000	480			
Corrected Total	1451,481	479			

a R Squared = ,162 (Adjusted R Squared = -,016)

Table9.

Tests of Between-Subjects Effects

Dependent Variable: Process

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	456,731(a)	122	3,744	1,344	,020
Intercept	4022,166	1	4022,166	1443,491	,000
@1stFixation	59,912	11	5,447	1,955	,032
ChosenColor	23,305	10	2,330	,836	,594
@1stFixation * ChosenColor	371,597	101	3,679	1,320	,035
Error	994,750	357	2,786		
Total	8179,000	480			
Corrected Total	1451,481	479			

a R Squared = ,315 (Adjusted R Squared = ,080)

Table10.

Function_Process

Process

Tukey HSD

Sound	N	Subset	
		1	2
HLL	60	3,08	
HLK	60	3,37	3,37
LLL	60	3,53	3,53
HHL	60	3,68	3,68
LLK	60	3,92	3,92
LHK	60	4,02	4,02
LHL	60		4,17
HHK	60		4,18
Sig.		,059	,154

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = 2,935.
a Uses Harmonic Mean Sample Size = 60,000.
b Alpha = ,05.

Confirmation

Table10a.

Tests of Between-Subjects Effects

Dependent Variable: Function_Confirmation

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	244.995(a)	84	2.917	.821	.864
Intercept	3681.310	1	3681.310	1036.160	.000
ChosenColour	**32.034**	**10**	**3.203**	**.902**	**.532**
Sound	**18.056**	**7**	**2.579**	**.726**	**.650**
ChosenColour * Sound	**206.640**	**67**	**3.084**	**.868**	**.758**
Error	1403.372	395	3.553		
Total	7062.000	480			
Corrected Total	1648.367	479			

a R Squared = .149 (Adjusted R Squared = -.032)

Table10a.

Tests of Between-Subjects Effects

Dependent Variable: Confirmation

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	46,997(a)	11	4,272	1,249	,252
Intercept	4974,053	1	4974,053	1453,666	,000
@1stFixation	46,997	11	4,272	1,249	,252
Error	1601,370	468	3,422		
Total	7062,000	480			
Corrected Total	1648,367	479			

a R Squared = ,029 (Adjusted R Squared = ,006)

Appendix III

Figure 6

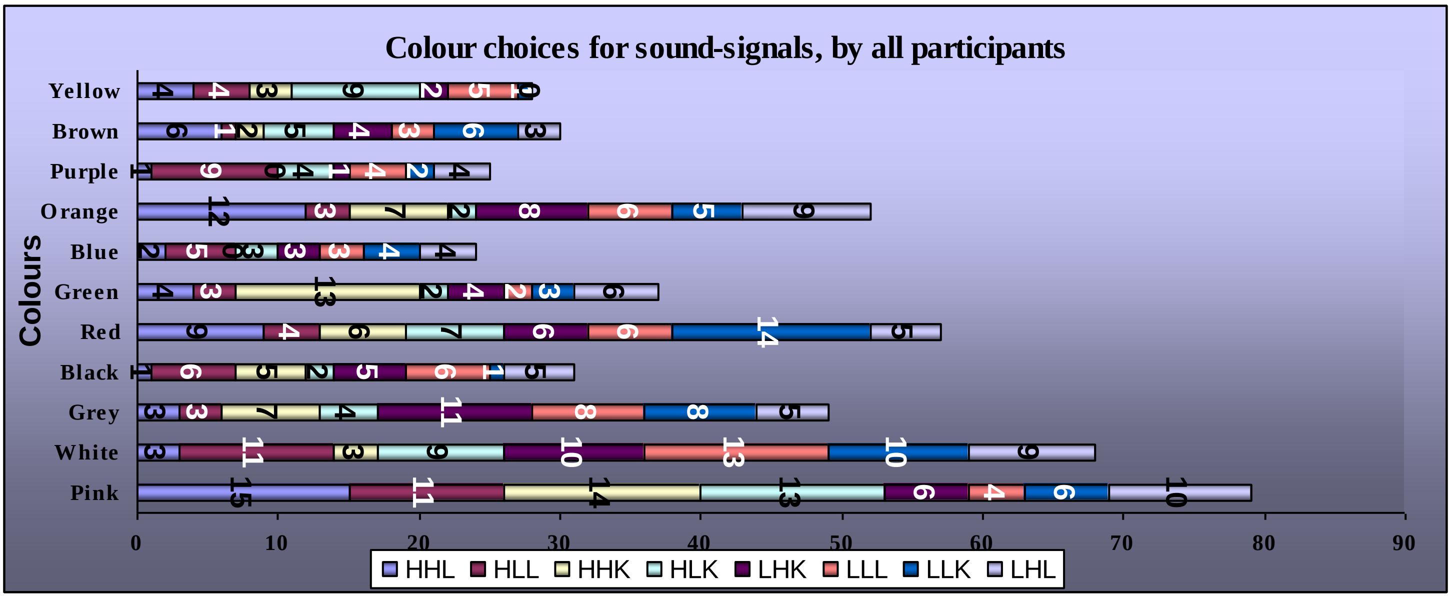

Figure 7

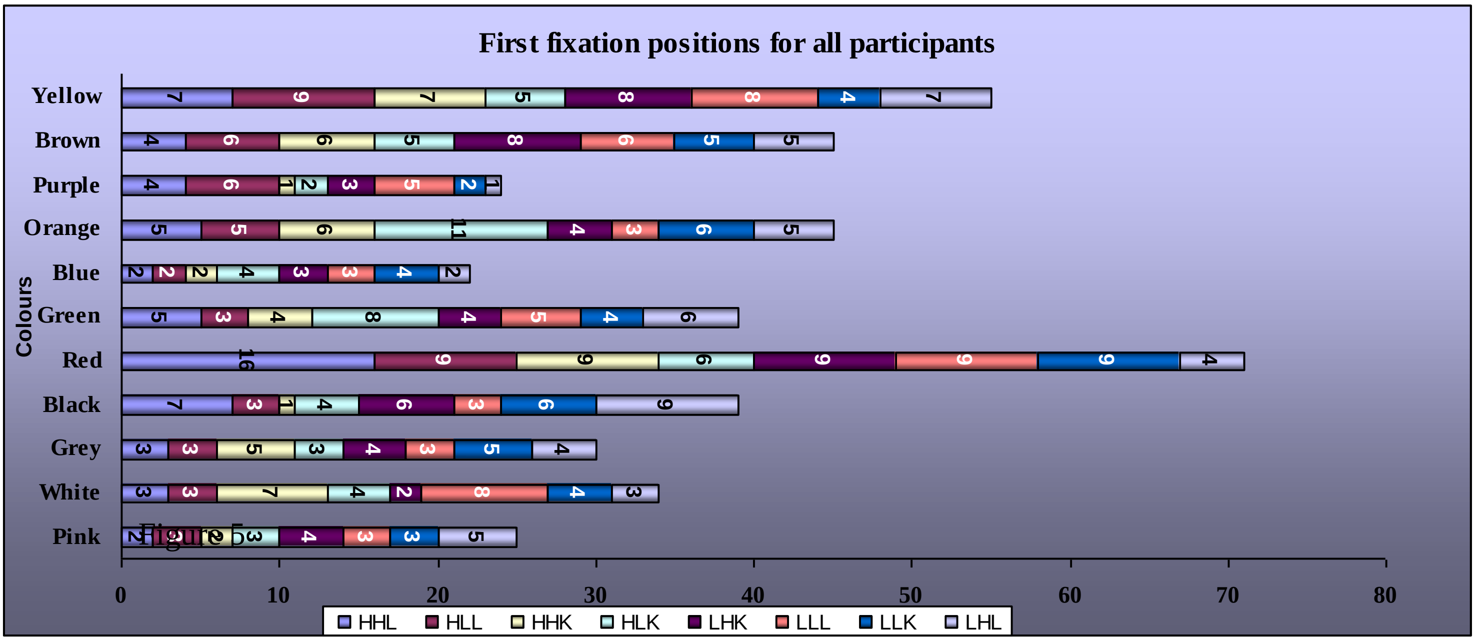

Table 2. Summary of colour which have been chosen and first fixation landed on, after participants listened to the sound signals.

Chosen colour	**Sound signals**	**First fixated colours**	**Sound signals**
Pink	HHL HHK HLK LHL	Red	HHL HHK LLL LLK
Pink and White	HLL	Red and Yellow	HLL LHK
White	LLL	Orange	HLK
Red	LLK	Black	LHL
Grey	LHK		

Figure 8

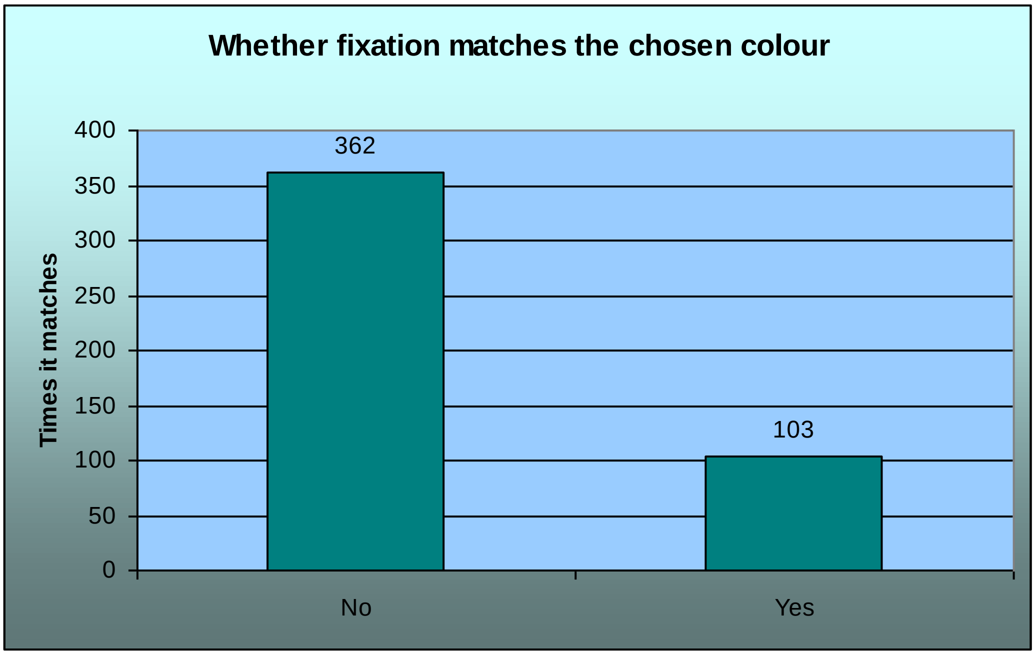

Figure 10a

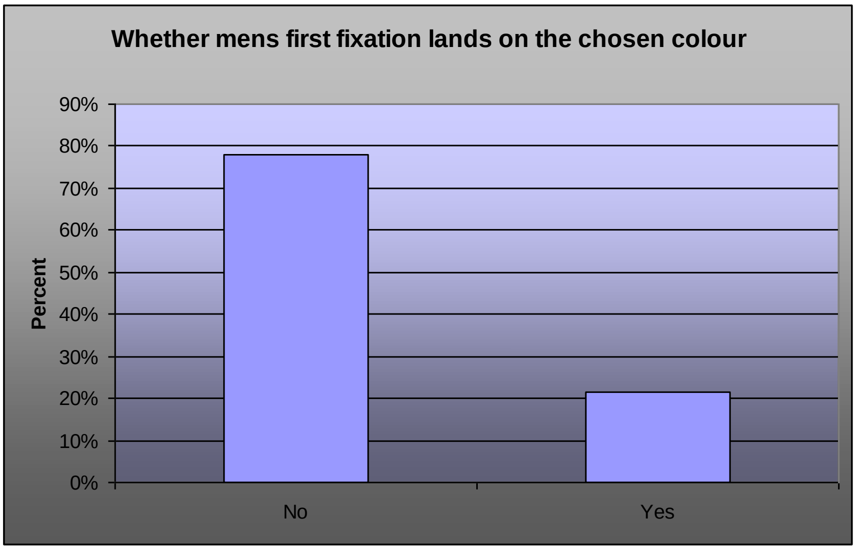

Figure 10b