Dichotic listening and semantic classification of specific, general, abstract and emotional words

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Abstract
Possible hemispheric differences in the processing of words belonging to four different lexical semantic categories: specific (e.g. *bird*), general (e.g. *animal*), abstract (e.g. *advice*), and emotional (e.g. *love*) were investigated using a dichotic listening paradigm. On the basis of findings in previous studies, a higher degree of lexical specificity as well as higher emotional content were hypothesized to lead to a greater involvement of the right hemisphere. This was expected to be reflected in a relatively smaller right ear advantage response for specific and emotional words as opposed to general and abstract words. Testwords and pseudowords were presented dichotically. Response times were measured while right-handed, normal-hearing Swedish speakers classified testwords as concrete or abstract. Results from the semantic classification task showed that abstract and emotional testwords were mainly judged to be abstract, whereas specific and general testwords were mainly classified as concrete. However, significantly more general than specific testwords were categorized as abstract, in line with the relatively lower imageability ratings of the general testwords, suggesting that they are associated with less sensory information than specific words. Response time analysis revealed that a majority of the participants, although not all, were faster to judge words presented to the right ear. Classification of words belonging to the abstract category was significantly slower as compared to other testword categories, regardless of ear of presentation. Although response times did not indicate any significant differences between testword categories that could be related to ear of presentation, it is possible that the complex task did not allow for early hemispheric differences in semantic processing to be detected.

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1. Introduction

1.1 Hemispheric lateralization of lexical semantic processing

In the majority of the population, the left hemisphere (LH) is language-dominant (Lezak, Howieson, Bigler, & Tranel, 2012). As an indication of this, aphasia is most commonly the result of LH lesions and temporary anaesthetization of the left, but not the right hemisphere (RH) disrupts speech production (Wada & Rasmussen, 1960). Today, neuroimaging studies of both healthy and clinical populations using silent word generation and naming tasks (Pujol, Deus, Losilla, & Capdevila, 1999; Rutten, Ramsey, van Rijen, Alpherts, & van Veelen, 2002) can also be added to the literature supporting a left-sided lateralization of linguistic processing. As regards speech perception and speech recognition, a division between a bilateral ventral speech processing stream and a strongly LH-dominant dorsal stream has been suggested (Hickok & Poeppel, 2007).

However, in contrast to this relatively left-hemispheric dominance for language, certain linguistic parameters have been found to be more RH dependent, for example emotion-related information such as emotional prosody (Buchanan et al., 2000; Ley & Bryden, 1982) and emotional words and sentences (Borod, Andelman, Obler, Tweedy, & Wilkowitz, 1992). As regards words' degree of concreteness, the processing of written abstract words has been found in fMRI studies to give rise to more left-lateralized activation of areas involved in phonological and verbal working memory processes, for example in the left frontal cortex, whereas concrete words have been associated with wide-spread, bilateral activity including sensory cortices (Binder, Westbury, McKiernan, Possing, & Medler, 2005; Sabsevitz, Medler, Seidenberg, & Binder, 2005; Sandberg & Kiran, 2014). Further supporting this finding, similar differences were seen in memory performance for concrete and abstract words presented to the two hemispheres via the left and right visual field, respectively (Oliveira, Perea, Ladera, & Gamito, 2013). That is, recall of concrete words was more accurate when they were presented to the RH, whereas abstract words were better recalled when presented to the LH, supporting the idea that the RH may be more involved in mental imagery processes associated with concrete words. In studies on oral word associations (Mårtensson, Roll, Apt, & Horne, 2011; Roll et al., 2012), participants with aphasia due to LH lesions were seen to have greater difficulties producing relevant responses to words at higher levels of abstraction, with the exception of one participant with anomia due to lesions to the left occipital lobe (further described in (Mårtensson, Roll, Lindgren, Apt, & Horne, 2013), who showed the opposite pattern, possibly due to lack of access to primary visual semantic features). The results from the above mentioned studies are in line with the 'dual coding theory' (Paivio, 1990; 2010) which proposed that abstract words are stored in the mental lexicon mainly in the form of a ”verbal” code (i.e. associated lexical items and discourse), whereas concrete words in addition are represented in terms of a ”non-verbal” or ”imagery” code (i.e. associated sensory information, of which visual information often constitutes a prominent part). To sum up, although there is evidence that although language is mainly LH lateralized, some types of semantic information associated with language processing may rather be more RH lateralized. The present study focused on possible differences in the hemispheric contributions when processing words associated with visual and emotional information.

Another aspect related to the assumed relatively greater RH contribution for mental imagery and concrete word processing is the degree of word specificity (also described by e.g. Rosch (1976) in terms of subordinate/ basic/ superordinate levels of categorization). Assuming that the RH is superior in mental imagery, it might be more involved in processing words whose referents are associated with detailed visual information (e.g. *carrot*) than words with more general, less visually specific meanings (e.g. *vegetable*). Results supporting this line of thought were obtained by Laeng, Zarrinpar, & Kosslyn (2003), who showed that the RH was superior in identifying pictures for concrete concepts at semantically specific levels (e.g. classifying a picture of a squirrel as a *squirrel*) as opposed to the LH, which instead showed an advantage in identifying pictures of concepts at a more general level (e.g. classifying a picture of a squirrel as a *rodent*). However, since their task involved pictures, it is still an empirical question whether similar differences in the degrees of hemispheric lateralization would also be present based on the semantic content of words. The present study aimed to target differences in specificity at the lexical semantic level of meaning processing using a verbal, auditorily presented test within the dichotic listening paradigm.

1.2 Testing hemispheric differences in semantic processing with dichotic listening

Dichotic listening studies have been widely used to investigate hemispheric specialization in the processing of sounds. Typically, different auditory stimuli are presented simultaneously to the right and left ear, e.g. CV syllables with different consonants (Hugdahl, 2000). In healthy, right-handed participants, results point to a right ear advantage/left-hemisphere dominance for processing speech sounds. A possible explanation for this right ear advantage (REA) is that the right ear has a more direct neural pathway to the left, language dominant hemisphere involving more nerve fibres and thus more cortical activity than the ipsilateral pathway (Kimura, 1967; Yasin, 2007). In addition to its application to studies on processing of speech sounds, the dichotic listening method can also be used to investigate the processing of word meaning.

Studies using the dichotic listening task to compare the relative hemispheric lateralization of the processing of different levels of word meaning abstraction are few. However, there are some early dichotic listening studies comparing semantic categories with different degrees of abstractness. Prior et al. (1984) compared abstract and concrete words in a dichotic listening experiment using a word recognition task, but did not find any significant differences in accuracy depending on ear of presentation. Ely et al. (1989) compared abstract, concrete and emotional words using a dichotically presented semantic task (categorizing words as abstract, concrete or emotional). They found a stronger REA for categorizing abstract words, whereas this effect was relatively smaller for emotional as well as concrete words. As discussed by the authors, a reason that they obtained significant results, while Prior et al. (1984) did not, might be that the semantic judgment task requires deep semantic processing, unlike the word recognition task used by Prior et al. (1984). Ely et al. (1989) used a stimulus set mainly consisting of single syllable nouns (e.g. *truth*, *horse*, although the words belonging to the emotional category were mostly verbs and adjectives (e.g. *weep*, *dead*). Prior et al. (1984) reported that they used single syllable nouns, although no examples of the stimuli were provided in the article.

Given the above background, the aim of the present study was, firstly, to investigate whether the right-hemisphere advantages for emotional and visuospatial processing found in previous studies would also be reflected in the processing of spoken words associated with emotional and visual meaning components. Secondly, in order to extend the hypothesis that processing of visually related word meanings may be more right hemisphere lateralized, concrete words at different levels of semantic specificity were included in the investigation, in addition to abstract and emotional words. Two different levels of concrete noun specificity (further described in sections 1.3 and 2.2 below) were thus compared in the present study.

1.3 The present study

In order to further examine whether variations in concreteness and emotional content are associated with different hemispheric involvement, the present study was carried out using a method based on Ely et al. (1989) but with some modifications. In a manner similar to that of Ely et al. (1989), words whose meaning differed in terms of rated imageability, which is strongly correlated with concreteness (Westbury & Moroschan, 2009), and emotional content were presented dichotically together with pseudowords. Response times were measured while participants made judgments of words' semantic category (abstract/concrete). However, the present study introduced an additional variable: semantic specificity. Thus, four wordtypes, all of which were nouns in order to control for possible effects of word class, were compared: specific (e.g. *soup*), general (e.g. *food*), abstract (e.g. *advice*) and emotional (e.g. *joy*).

1.3.1 Hypotheses: Semantic classifications

Based on the distribution of concreteness/imageability values for the four wordtypes (see paragraph 2.2), specific and general testwords were expected to be classified mainly as concrete, whereas abstract and emotional testwords were hypothesized to most often be categorized as abstract. In addition, considering the slightly lower imageability values of general words than specific words, the former were expected to be judged as abstract to a relatively greater degree. Emotional words were expected to be categorized as concrete more often than abstract words, mainly due to their relatively higher imageability values, but possibly also due to their association with affective experiential information (cf. (Kousta, Vigliocco, Vinson, Andrews, & Del Campo, 2011).

Table X: Hypotheses for abstract/concrete classifications of testword types.

Testword type	**Example**	**Imageability**	**Hypothesized distribution of classifications**
Specific	carrot	highest	Concrete
General	food	high, but lower than for specific words	Mainly concrete, but abstract to some degree
Abstract	idea	low	Abstract
Emotional	anger	intermediate	Mainly abstract, but concrete to some degree

1.3.2 Hypotheses: Response times

Firstly, a general LH/right ear advantage (REA) for the processing of all four testword categories was expected, in line with previous dichotic listening research (e.g. (Hugdahl, 2000; Kimura, 1967). This was expected to be seen as overall shorter response times when words were presented in the right ear.

Secondly, emotional word processing was hypothesized to be less LH lateralized as compared to the processing of the abstract (low emotional arousal) testword category, in line with Borod et al. (1992) and Ely et al. (1989). Thus, the hypothesized REA (shorter response times for words) was expected to be less pronounced for emotional words than for abstract words.

Thirdly, the processing of words whose meaning is at a relatively specific level (e.g. *soup*) was expected to be less LH lateralized as compared to words at a more general level in the same semantic hierarchy (e.g. *food*), which do not have as clearly imageable referents. Relating the idea that the processing of highly specific/concrete words may involve activation of more detailed visual information to the results from e.g. the above mentioned picture identification task of Laeng et al. (2003), the visual specificity associated with these words' referents was expected to involve the RH to a larger extent than words with referents at a more general level of meaning. It was therefore hypothesized that the response times would be relatively shorter for specific words presented in the left ear, reflecting a relatively less pronounced REA as compared to general words, which instead were expected to behave more as abstract words, showing a relatively more pronounced REA.

Table Y: Hypotheses for effects of testword type on REA and response times.

Testword type	**Example**	**Types of associated semantic information hypothesised to increase RH involvement**	**Expected degree of right ear advantage (REA)**	**Expected effect on response times**
Specific	carrot	visual	weaker	relatively smaller increase in RT when words are presented in the left ear
General	food	-	strong	relatively larger increase in RT when words are presented in the left ear
Abstract	idea	-	strong	relatively larger increase in RT when words are presented in the left ear
Emotional	anger	emotional + visual	weaker	relatively smaller increase in RT when words are presented in the left ear

2. Method

2.1 Participants

Thirty-eight native speakers of Swedish were initially recruited through advertising in the Lund University area. All participants had their hearing tested with Békésy audiometry and their handedness assessed using a revised version of the Edinburgh Handedness Scale (Oldfield, 1971), see Appendix 4.

In order to be included in the study, participants had to be right-handed with normal hearing defined as pure-tone hearing thresholds ≤ 20 dB Hearing Level (HL) (ISO 2004) for frequencies 250, 500, 1000, 2000, 4000, and 8000 Hz. Eight participants did not meet this criteria and were therefore excluded. The final sample thus consisted of 30 participants (21 female) in the age range of 20-64 years (*M*=28, *SD*=9.6). None of the participants reported any current or previous language difficulties. The study was performed in conformity to the Declaration of Helsinki and informed consent was obtained from all participants prior to the test. Participants received either payment or a gift for their participation.

2.2 Stimuli

The stimuli consisted of 120 one to two syllable nouns divided into the four semantic categories described in paragraph 1.3 (specific, general, emotional, abstract). The stimulus sets of the different categories were counterbalanced for number of syllables as well as word frequency in the Stockholm Umeå Corpus (Ejerhed, Källgren, Wennstedt, & Åström, 1992). Specific and general testwords were taken from different lexical semantic hierarchies, e.g. *bord-möbel* 'table-furniture'; *banan-frukt* 'banana-fruit'. Imageability (≈ degree of concreteness) values for English translations of the words were obtained from the MRC Psycholinguistic database (Coltheart, 1981). Mean imageability was lowest for abstract words (M=356, SD=57), followed by emotional words (M=460, SD=67), general words (M=538, SD=76) and was highest for specific words (M=604, SD=32). An independent-measures ANOVA with word category (specific/general/abstract/emotional) as fixed factor showed that imageability values differed significantly between each category (all p values <

0.001, Sidak correction for multiple comparisons). Ratings of emotional arousal were performed following the main experiment in the present study, and were highest for emotional words (M=553, SD=83), relatively low for abstract words (M=331, SD=114) and lowest for specific (M=233, SD=97) and general (M=231, SD=82) words. An independent measures ANOVA with word category (specific/general/abstract/emotional) as fixed factor revealed significant differences in emotional arousal between the categories. Multiple comparisons with Sidak correction showed that there were differences between all word categories (p-values<0.001) except for specific and general words which had an equally low rating for emotional arousal (p=1.0). For each test word, a corresponding pseudoword was created with the same number of syllables and the same initial consonant, or in some cases consonant cluster (e.g. *fågel-figar* /fo:gel/-/fi:gar/, *glädje-glamra* /glɛ:dje/-/glamra/). In line with the aim of the study to detect possible hemispheric differences in the processing of word meaning, pseudowords were presented along with existing words in order to restrict the presentation of testwords to one ear/hemisphere at a time. Pseudowords were chosen since they have previously been successfully used in dichotic listening (Ely et al. (1989), and since other types of competitive stimulation (i.e. non-speech) such as white noise and crowd noise has been found to be less efficient (K. McFarland, McFarland, Bain, & Ashton, 1978). The full set of testwords and pseudowords used in the study is presented in Appendices 1-3.

The stimuli were recorded with a Neuman U87AI microphone in an anechoic chamber using the sound-editing software Audacity. Words and pseudoword pairs were spoken by a female native speaker of Swedish with neutral intonation and normal speech rate. In the recording of every other pair, the pseudoword was pronounced first. The subsequent sound editing was also carried out using Audacity. Each stimulus was cut at the onset and end of the soundwave and saved as a separate file. Files with the word and the pseudoword in the right and left channels were then created. When necessary, initial fricatives were shortened so that the stimuli aligned at the onset of the vowel. All stimuli were then normalized using MatLab to a target RMS amplitude of 17.41 dB.

2.3 Procedure

Partcipants were seated in front of a computer with a Dell EI72FP 17´ screen in a quiet room. Written instructions were displayed on the computer screen prior to the experiment. Participants were instructed to identify the real word in the word/pseudoword mixture and to classify it as either abstract or concrete. Participants were informed that concrete words were defined as those referring to something one can see and touch, abstract words as something one cannot see and touch (see Appendix 3 for an English translation of the full set of instructions).

The speech signals (word/pseudoword pairs) were presented dichotically using E-prime ver. 2.0 on a personal computer. The computer had a SIS7012 Audio Driver integrated on the motherboard and was connected to a GSI 16 Audiometer (Grason & Stadler Inc.) and a pair of circumaural California Headphones Silverado earphones. The complete equipment set-up was calibrated in accordance with IEC 60318-2 and ISO 389-8 using a Brüel and

Kjaer Impulse Precision Sound Level Meter type 2209 with a 4144 microphone in a 4152 ear simulator (IEC 1998; ISO 2004). A 1000 Hz calibration tone with equal average RMS as the speech signals (17.41 dB) was used for the calibration of the speech signals.

The stimuli were presented at 70 dB SPL in a pseudorandomized order with the real word presented to each ear in no more than three consecutive trials. There was a 3000 ms interstimulus interval during which the participant could respond before the experiment automatically moved on to the next trial. The task was to distinguish the real word and categorize it as either concrete (K) or abstract (A) by button press. Responses were made on a PST Serial Response Box by pressing the two rightmost keys with the right hand's index and middle finger. In order to avoid shorter response times for responses made with the index finger, the index/middle finger response button order used for concrete/abstract were counterbalanced between participants. Before the real test, participants completed a practice task with 12 trials (four words of each category).

2.4 Post-test hearing assessment

All participants' hearing was assessed post-test by means of fixed-frequency Békésy audiometry estimating their pure tone hearing thresholds for frequencies 250, 500, 1000, 2000, 4000, and 8000 Hz. The audiometry was carried out using a personal computer with an internal Realtek AC97 soundcard (16 bits/44.1 kHz) and a pair of circumaural sound-attenuating Sennheiser HDA 200 earphones. A custom-made computer program (Brännström & Grenner, 2008) generated and presented all stimuli and recorded the participants' responses. The pure-tone stimuli generation and the calibration of the set-up was in accordance with ISO 389-8 (ISO, 2004) and the complete set-up was calibrated using a Brüel and Kjaer 2231 sound level meter with a 4134 microphone in a 4153 artificial ear according to IEC 60318-1 (1998) and IEC 60318-2 (1998). The stimuli used were pulsed pure tones. The pure tones were gated on during 240 ms including 20 ms rise and fall times with a 160 ms silent interval between presentations. Seventy-five presentations were used per frequency. The rate of the intensity change was 2.5 dB per second. The arithmetic mean of all reversals of the individual frequencies was used to calculate the hearing threshold at each frequency.

2.5 Post-test questionnaires and emotional word ratings

Following the dichotic listening test, all participants completed two questionnaires. The first one included ratings of the difficulty of identifying words and the difficulty of making the semantic judgments on five-point scales, as well as questions about the participants' strategies for performing the task. For exemple they were asked to decribe in their own words what they based their abstract/concrete classifications on, to give some examples of words that were easy vs. difficult to classify, and whether they felt that they attended to each ear equally. The second questionnaire included demographic information such as e.g. age, sex and regional dialect, as well as the revised version of the Edinburgh Handedness scale (Oldfield, 1971). Finally, each participant rated all testwords used in the dichotic listening experiment as to their degree of emotional arousal on a seven-point scale. The words and the rating scale were presented visually in random order on a personal computer with a Dell SE177FPf 17´ screen using E-prime ver. 2.0. Participants were instructed that words that evoked very strong emotional arousal should be given scores at the highest end of the scale, whereas words that were deemed to be completely neutral as regards emotional arousal should be given the lowest score. There was no time limit for responding, although the instructions emphasized that word ratings should be made based on the first impression.

2.6 Statistical analysis

Comparison of concrete/abstract responses to the different testword categories (specific/general/abstract/emotional) was made with Chi Square tests using Preacher (2001). Response times were analyzed using SPSS by means of within-subjects ANOVAs with ear and testword category as independent variables. Post hoc comparisons were carried out using Sidak tests.

3. Results

3.1 Semantic classifications

The distribution of abstract/concrete classifications for the four testword categories are shown below in Tab. 1a-c and Fig. 1. Statistical analysis showed that words were classified as concrete significantly more often than abstract if they belonged to the specific (e.g. *soup*) ($c2=521.294$, $p<0.0001$, $df=1$) as well as general (e.g. *food*) ($c2=360.928$, $p<0.0001$, $df=1$) testword categories. However, a comparison of the number of specific vs. general words which were categorized as abstract revealed that a significantly greater number of general words were judged as abstract ($c2=14.44$, $p=0.0001$, $df=1$). Comparisons involving abstract (e.g. *task*) and emotional words (e.g. *joy*) showed that testwords from both categories were classified as abstract more often than concrete (abstract: c2=432.265, p<0.0001, df=1; emotional: c2=512.305, p<0.0001, df=1). These classification differences were statistically significant regardless of ear for testword presentation.

Table 1a: Results for semantic classification task

		Semantic classification		Total
		concrete	abstract	
Testword category	specific	739	84	823
	general	688	141	829
	abstract	112	707	819
	emotional	92	748	840
Total		1631	1680	3311

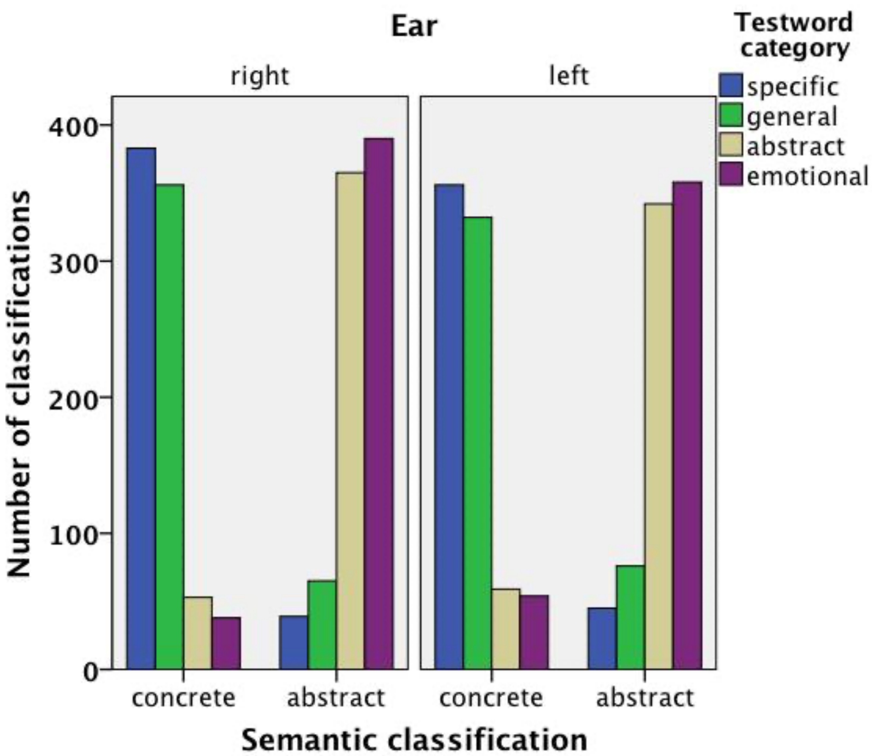
Table 1b: Results for semantic classification task: right ear.

		Semantic classification		Total
		concrete	abstract	
Testword category	specific	383	39	422
	general	356	65	421
	abstract	53	365	418
	emotional	38	390	428
Total		830	859	1689

Table 1c: Results for semantic classification task: left ear.

		Semantic classification		Total
		concrete	abstract	
Testword category	specific	356	45	401
	general	332	76	408
	abstract	59	342	401
	emotional	54	358	412
Total		801	821	1622

Figure 1: Distribution of semantic classifications of the four testword categories for right and left ear testword presentation.



3.2 Response times

Initial response time analysis showed that the majority of the participants (N=22) were faster to process words presented to the right ear (from now on referred to as the right-ear advantage (REA) group). However, the opposite pattern was seen in a subgroup (N=8), who showed an overall left-ear advantage (from now on referred to as the LEA group). Due to this difference, these two groups were analyzed separately. Mean response time values for the REA group are summarized below in Table 2/Figure 2 and for the LEA group in Table 3/Figure 3.

Table 2: Mean response times (RT) in ms for judging testwords as 'concrete' or 'abstract' for the four testword categories and for right and left ears in the REA group.

		RT /ear (ms)		Difference (ms)
		right	left	
Testword category	specific	1355	1574	219
	general	1354	1523	169
	abstract	1474	1633	159
	emotional	1432	1541	109

Figure 2: Mean response times (ms) for testword category and ear in the REA group.

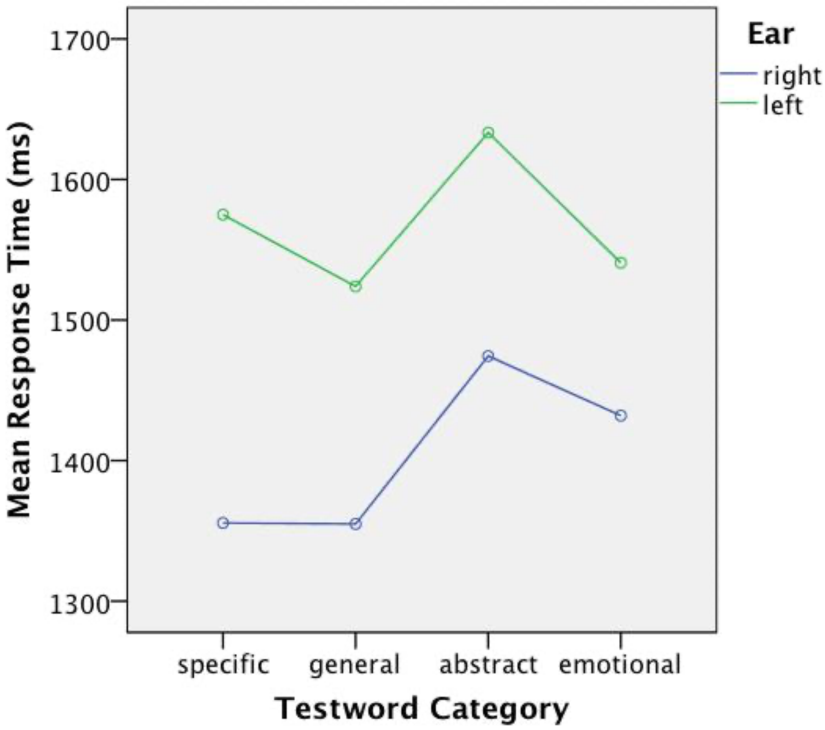
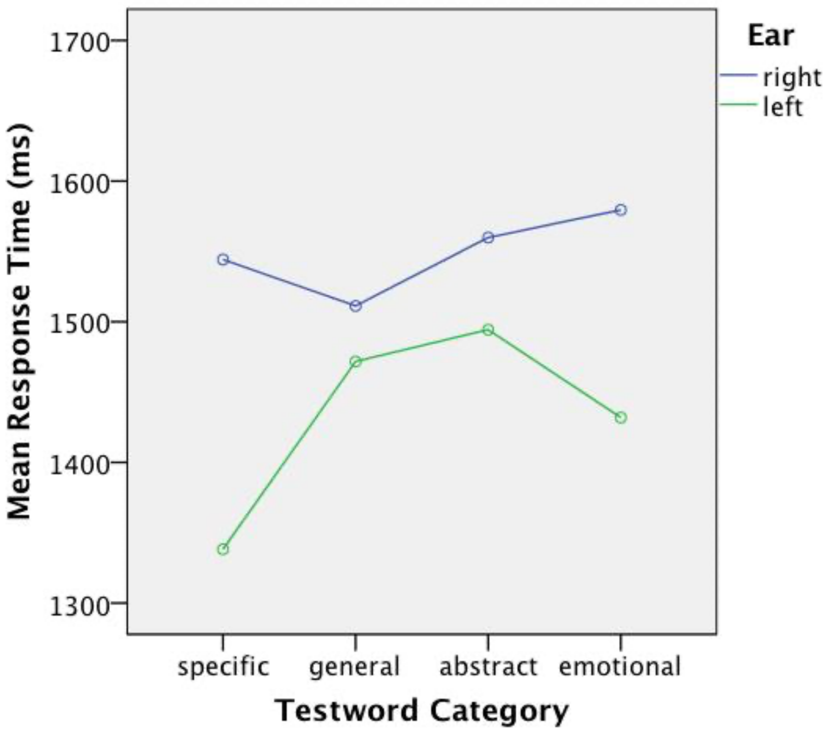


Table 3: Mean response times (ms) for for judging testwords as 'concrete' or 'abstract' for the four testword categories and for right and left ears in the LEA group.

		RT /ear (ms)		Difference (ms)
		right	left	
Testword category	specific	1544	1338	206
	general	1511	1472	39
	abstract	1560	1494	66
	emotional	1579	1432	147

Figure 3: Mean response times (ms) for each testword category and ear in the LEA group.



Separate within-subjects ANOVAs with ear and wordtype as independent variables were carried out for the REA and LEA groups. In the REA group, there were main effects of both ear (F=50.389, p<0.001) and wordtype (F=6.503, p=0.003) but no interaction (F=0.483, p=0.698). Post hoc Sidak tests revealed that the effect of wordtype was due to the fact that response times to words of the abstract category were significantly slower as compared to both specific words (p=0.012) and general words (p=0.005). Since the difference was observed to be as large as 50 ms between the mean response times for specific and general words for the left ear in the REA group (see Tab.

2), these two test categories were compared with a separate within-subjects ANOVA, but the difference was found not to be significant ($F=0.933$, $p=0.345$). In the LEA group, there was a main effect of ear only ($F=11.780$, $p=0.011$).

4. Discussion

4.1 Semantic judgments

Results from the semantic classification task showed that the majority of words from the emotional and abstract testword categories were judged to be abstract, whereas most words belonging to the general and specific categories were judged as being concrete (Tab. 1, Fig. 1). These results are in agreement with the fact that imageability ratings were at the high end of the scale for the specific and general testwords used in the study, and at the lower end for the emotional and abstract testwords. Furthermore, general words (e.g. *mat* 'food') were found to be categorized as abstract significantly more often than specific words (e.g. *soppa* 'soup'), as might be predicted by the difference in concreteness (imageablity) between these two levels of lexical specificity. This difference in semantic judgments supports the hypothesis that words at a relatively general level of semantic specificity are relatively less clearly related to salient sensory information than words a more fine-grained level of specificity. Thus, differences in the amount of sensory information associated with a word's meaning can be reflected not only in word imageability ratings, but also in a task where words are categorized as either concrete or abstract.

As regards the emotional testwords, the fact that their imageability values were higher than those of the abstract words, as well as the fact that their high emotional arousal ratings suggest that they are associated with affective experiential information, raised the expectancy that emotional words would be judged as concrete to a greater extent than abstract words. This was, however, not the case. Instead, there was actually a slight difference (although not significant) in the opposite direction: 748 words of the emotional testword category were judged as being abstract, compared to 707 words of the abstract testword category (see Tab. 1). This pattern emerged despite the fact that emotionality was not included in the definition of abstract words given in the instructions, which only emphasized abstract words' lack of visible and touchable referents. Participants also frequently reported in the post-test questionnaire that if the word had emotional content, they considered it to be abstract. One possible explanation for this is that it reflects schoolbook definitions, where words for emotions are often used to exemplify abstract words. The learned strategy to judge words with emotional content as abstract might then have sometimes overruled any influence from imageability effects during decision-making.

4.2 Response times

The main difference in response time depending on testword type was that in the right-ear advantage (REA) group, abstract words, regardless of ear of presentation, were processed significantly slower than specific and general words. This is consistent with the well-documented 'concreteness effect' (Paivio, 2010), i.e. that concrete words with high imageability are generally processed faster and more accurately as compared to abstract, low imageability words. Abstract words also differed from emotional words in the same direction, a difference which did not, however, reach significance.

4.2.1 Response times and choice of testwords

In contrast to what was hypothesized, response times indicated no interactions between ear and wordtype which would support different degrees of hemispheric lateralization related to the testwords' semantic category. As regards general and specific words, one possible reason for this is that hemispheric differences associated with processing general and specific levels might be more distinct at more fine-grained levels of semantic specificity. Laeng et al. (2003) found evidence for a relative right-hemisphere lateralization of picture naming at specific levels, but their general/specific distinction was made between two levels of specificity that involved relatively more detailed semantic content (e.g. *bird-robin; woman-Marilyn Monroe*) than the ones used in the present study (e.g. *animal-bird*).

It might also had been advantageous to increase the difference in semantic specificity (and possibly imageability) by using even less semantically distinct testwords for the general level and/or even more semantically fine-grained for the specific level. However, this was not done for two main reasons. Firstly, if very general words were used in all instances where possible, the same testword would have to be used for several trials. For example, the general term *grej* 'thing' could arguably be a superordinate level term for *såg* 'saw' as well as *pistol* 'pistol'. Thus, in order to avoid re-use of testwords, the relatively less general superordinates *verktyg* 'tool' and *vapen* 'weapon' were chosen instead. Moreover, using even more fine-grained specific levels would tend to make testwords longer due to the use of compound words (e.g. *motorsåg* 'chain saw'; *automatpistol* 'semi-automatic pistol') thus exceeding the one to two syllable limit set for words used in the dichotic-listening stimulus set.

4.2.2. Response times and task

The fact that no hemispheric differences between testword categories could be detected in the response time analysis might also be explained by the demands of the task. Judging whether a word is concrete or abstract (i.e. refers to something you can see and touch /does not refer to something you can see and touch) might not necessitate sufficient differences in the kinds and degrees of semantic activation for hemispheric differences to be measurable in the response times. Rather, forming a rough sensory semantic representation may be sufficient for judging whether a word refers to something concrete or abstract. Should this be the case, the particular semantic classification task used in the present study might not capture differences related to the more fine-grained semantic distinctions between general and specific testword categories.

4.2.3. Response times and the LEA-group

Finally, it was observed that the response time results were more complex than expected in that not all of the right-handed participants showed a REA in their response times. This was despite the fact that they all had normal hearing and should most likely have a language dominant left hemisphere. One possibility is that there were differences in the degree of right-handedness between the REA and LEA groups which were not captured by the handedness questionnaire. Kopiez (2010) found that other measures of handedness, e.g. speed of buttonpresses, yield partially different results than questionnaires.

Even given that all participants were equally right-handed, this might not always be reflected in dichotic listening data. Hiscock & Kinsbourne (2011) raise the question that reaction times measured in a dichotic listening test may not reliably reflect hemispheric lateralization of language. For example, although 95-99% of right-handed subjects have left-lateralized language as measured by the Wada procedure (Wada & Rasmussen, 1960), only about 80-85% show a REA in dichotic listening tests. In addition, the same participants may even switch between a REA and a LEA on different test occasions. Hiscock & Kinsbourne (2011) discuss the possibility that this discrepancy might be explained by attentional factors. For example, they suggest that verbal stimuli and verbal 'mental set' can prime the left hemisphere to a certain degree, thus making the REA for detecting those stimuli even more pronounced. In the present study, the task was expected to involve accessing non-verbal, sensory semantic information to determine word concreteness, which could instead make the REA relatively less pronounced. Furthermore, a more complex task requiring heavier processing might involve both hemispheres to a greater degree, as shown in a quantitative review of studies within the Dimond paradigm, a method where stimuli are visually presented to different hemispheres (Leblanc-Sirois & Braun, 2014). Given that there are several steps in the present experiment (distinguishing the real word, making the abstract/concrete decision, pressing the button), and that response times were rather long (mean RTs were in the range of 1338-1663 ms), the task used in the present study might fall into the complex part of the spectrum discussed by Leblanc-Sirois & Braun (2014). Thus, if their theory can be extended to the interpretation of results from auditory tasks, any possible overall REA would be smaller because of task difficulty. Hickok & Poeppel (2007) also suggest that the neural mechanisms involved in integrating information over longer timescales are more right-hemispheric. Taken together, these factors may contribute to the fact that a REA could not be seen in all participants in the present investigation.

4.3 General discussion

The semantic judgment test revealed that abstract and emotional testwords were largely classified as abstract and specific and general words as concrete. Furthermore, there was a difference in the distribution of abstract/concrete judgments of the specific and general categories, with the general words being judged as abstract more frequently than specific words, supporting the hypothesis that general words are associated with less sensory information and thus can be considered as more abstract. As regards response times, significantly longer latencies were obtained for abstract testwords than for specific and general testwords, in accordance with previous findings that words with low imageability are more difficult and take relatively more time to process (Paivio, 1990).

Although the above results were robust, no statistically significant interactions of ear of presentation and testword category could be seen in the data. Thus, the present study, like Prior et al. (1984), but unlike Ely et al. (1989), did not offer any support for the hypothesis that degree of concreteness and emotional content modulates the degree of hemispheric involvement in semantic processing. This was despite the fact that the present method was more similar to Ely et al. (1989) who also used a semantic classification task, than to Prior et al. (1984), who used a word recognition task. There were, however, some differences in the procedure of the present study compared to Ely et al. (1989) which might have made differences in hemispheric processing less pronounced/more difficult to capture. Firstly, Ely et al. (1989), had only a 1000 ms window to respond, but participants rated the stimuli for emotional arousal and imageability before the test in order to familiarize themselves with them. In contrast, in the present study, all word ratings were performed post-test in order not to introduce repetition effects; however, participants were given more time to respond (3000 ms). Thus, in Ely et al. (1989) response times were measured for semantic judgments made when imagery and emotional experiences had previously been activated in memory, but less time was given to make the decisions. In the present study, semantic classification decisions were made without previous exposure to the testwords, meaning so that any activation of imagery needed for making semantic judgments had to occur before the decision was made. Secondly, in Ely et al. (1989) participants made decisions as to whether words were abstract, concrete or emotional. In the present study, participants had to choose between only two categories, abstract and concrete, but the testword set contained four different lexical categories (specific, general, emotional, abstract) associated with different levels of imageability and emotional arousal. Taken together, these differences may have resulted in a more complex task in the present study. Given task complexity and the relatively long overall response times, it cannot be excluded that there may be early differences in semantic processing which were not captured using the present method. Possible different hemispheric contributions to word meaning processing might be revealed using methods with more fine-grained temporal resolution, for example EEG (Bayazıt, Öniz, Hahn, Güntürkün, & Özgören, 2009; Yasin, 2007). Further investigations comparing the processing of these different lexical categories could benefit from using such methods and thus make it possible to study semantic processing on a more detailed level.

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Appendix 1: English translations of stimuli words

Specific		**General**		**Abstract**		**Emotional**	
Swedish	**English**	**Swedish**	**English**	**Swedish**	**English**	**Swedish**	**English**
fågel	bird	djur	animal	frihet	freedom	kärlek	love
banan	banana	frukt	fruit	råd	advice	glädje	joy
träd	tree	växt	plant	rykte	rumor	oro	worry
torg	market	plats	place	löfte	promise	sorg	sorrow
såg	saw	verktyg	tool	moral	moral	lycka	luck
mangel	mangle	maskin	machine	plikt	duty	mod	courage
dator	computer	pryl	gadget	datum	date	lust	lust
bil	car	fordon	vehicle	stil	style	längtan	yearning
bord	table	möbel	furniture	svar	answer	humor	humour
regn	rain	väder	weather	prestige	prestige	skräck	horror
byxa	trousers	kläder	clothes	mognad	maturity	tröst	comfort
granit	granite	sten	stone	uppgift	task	skam	shame
kvinna	woman	person	person	magi	magic	ilska	anger
pistol	pistol	vapen	weapon	visdom	wisdom	sjukdom	disease
sommar	summer	årstid	season	påhitt	idea	lättnad	relief
Jorden	Earth	planet	planet	ordning	order	chock	shock
kaffe	coffee	dryck	beverage	tanke	thought	framgång	success
vatten	water	vätska	fluid	arv	heritage	hat	hatred
tårta	cake	bakverk	pastry	krav	demand	kris	crisis
morot	carrot	grönsak	vegetable	term	term	förakt	contempt
hus	house	byggnad	building	rutin	routine	fest	party
peppar	pepper	krydda	spice	bevis	proof	kaos	chaos
fyrkant	square	form	shape	fas	phase	död	death
vals	waltz	dans	dance	tendens	tendency	spänning	excitement
spade	spade	redskap	tool	behov	need	fördel	advantage
frisör	hairdresser	yrke	occupation	metod	method	krig	war
orm	snake	reptil	reptile	brist	lack	skada	harm
bi	bee	kryp	bug	fakta	fact	liv	life
boll	ball	grej	thing	mängd	amount	problem	problem
soppa	soup	mat	food	avsikt	intent	vänskap	friendship

Appendix 2: Word-pseudoword pairs

Specific		General		Abstract		Emotional	
W	PsW	W	PsW	W	PsW	W	PsW
fågel	figar	djur	djam	frihet	frugit	kärlek	kjoldig
banan	betak	frukt	frelk	råd	rul	glädje	glamra
träd	tram	växt	vird	rykte	rinko	oro	one
torg	terp	plats	plunk	löfte	lebka	sorg	silt
såg	sun	verktyg	vongter	moral	mödek	lycka	lonte
mangel	mudar	maskin	mirgol	plikt	plesk	mod	mis
dator	doger	pryl	pruk	datum	duner	lust	lygd
bil	buf	fordon	finpud	stil	stöm	längtan	lestor
bord	birn	möbel	miges	svar	svel	humor	hivel
regn	ralp	väder	vulan	prestige	prinkus	skräck	skrum
byxa	bonta	kläder	klosit	mognad	milklur	tröst	trenk
granit	grutan	sten	stof	uppgift	unnsang	skam	skod
kvinna	kvalle	person	pufid	magi	murö	ilska	isbre
pistol	purtas	vapen	venit	visdom	valnad	sjukdom	sjårbal
sommar	sännas	årstid	åsprag	påhitt	purall	lättnad	lasskin
Jorden	jendal	planet	plefir	ordning	ojtrask	chock	skynn
kaffe	konni	dryck	dröng	tanke	tespa	framgång	frölkan
vatten	verrut	vätska	vanple	arv	ant	hat	hås
tårta	tille	bakverk	bulting	krav	krip	kris	krul
morot	mekor	grönsak	gromdis	term	tann	förakt	felonk
hus	hek	byggnad	bannbal	rutin	rybod	fest	farp
peppar	pottig	krydda	kralle	bevis	bamal	kaos	keam
fyrkant	falkons	form	fump	fas	fud	död	dib
vals	vilk	dans	dilt	tendens	talbind	spänning	spallest
spade	spöni	redskap	runtrok	behov	bosik	fördel	filpån
frisör	franål	yrke	ymla	metod	miner	krig	kryd
orm	olk	reptil	riskon	brist	brall	skada	skobe
bi	bå	kryp	kreb	fakta	filde	liv	lad
boll	batt	grej	grit	mängd	malbs	problem	priglot
soppa	siffe	mat	miv	avsikt	arpenk	vänskap	vurspon

Appendix 3: Words with values for frequency, imageability and emotional arousal

Swedish	English	Wordtype	Frequency	Imageability	Emotional arousal
banan	banana	specific	5	644	180
bi	bee	specific	4	623	213
bil	car	specific	371	638	197
boll	ball	specific	17	622	190
bord	table	specific	134	582	130
byxa	trousers	specific	23	630	150
dator	computer	specific	212	-	197
frisör	hairdresser	specific	2	-	170
fyrkant	square	specific	3	610	127
fågel	bird	specific	68	614	233
granit	granite	specific	1	-	153
hus	house	specific	354	606	223
Jorden	Earth	specific	1	580	417
kaffe	coffee	specific	93	618	273
kvinna	woman	specific	573	626	440
mangel	mangle	specific	0	-	160
morot	carrot	specific	15	577	170
orm	snake	specific	7	627	307
peppar	pepper	specific	3	587	177
pistol	pistol	specific	24	613	463
regn	rain	specific	44	618	300
sommar	summer	specific	165	618	447
soppa	soup	specific	18	604	170
spade	spade	specific	2	538	130
såg	saw	specific	21	531	153
torg	market	specific	44	583	187
träd	tree	specific	121	622	243
tårta	cake	specific	5	624	250
vals	waltz	specific	3	524	257
vatten	water	specific	422	632	280
bakverk	pastry	general	2	-	227
byggnad	building	general	83	578	160
dans	dance	general	75	510	387
djur	animal	general	218	575	300
dryck	beverage	general	30	565	210
fordon	vehicle	general	24	593	173
form	shape	general	512	471	190
frukt	fruit	general	25	587	203
grej	thing	general	20	358	143
grönsak	vegetable	general	1	598	180
kläder	clothes	general	91	629	240
krydda	spice	general	8	592	197
kryp	bug	general	3	-	247
maskin	machine	general	66	575	187
mat	food	general	151	539	333
möbel	furniture	general	20	588	150
person	person	general	555	562	253
planet	planet	general	9	578	327
plats	place	general	443	377	200
pryl	gadget	general	3	-	153
redskap	tool	general	31	391	160
reptil	reptile	general	0	579	227
sten	stone	general	115	612	153
vapen	weapon	general	87	546	510

verktyg	tool	general	45	538	173
väder	weather	general	85	537	300
vätska	fluid	general	26	-	177
växt	plant	general	74	605	200
yrke	occupation	general	46	406	250
årstid	season	general	18	495	317
arv	heritage	abstract	41	-	300
avsikt	intent	abstract	64	286	310
behov	need	abstract	245	327	400
bevis	proof	abstract	54	339	320
brist	lack	abstract	128	302	370
datum	date	abstract	18	501	167
fakta	fact	abstract	6	302	230
fas	phase	abstract	30	319	170
frihet	freedom	abstract	83	437	610
krav	demand	abstract	240	-	503
löfte	promise	abstract	27	320	477
magi	magic	abstract	6	458	387
metod	method	abstract	192	304	180
mognad	maturity	abstract	9	-	357
moral	moral	abstract	25	341	477
mängd	amount	abstract	185	316	170
ordning	order	abstract	153	352	303
plikt	duty	abstract	21	346	467
prestige	prestige	abstract	9	394	463
påhitt	idea	abstract	2	319	283
rutin	routine	abstract	43	341	317
rykte	rumour	abstract	36	353	373
råd	advice	abstract	100	352	303
stil	style	abstract	78	464	293
svar	answer	abstract	192	368	250
tanke	thought	abstract	306	348	393
tendens	tendency	abstract	54	261	243
term	term	abstract	82	368	153
uppgift	task	abstract	465	410	270
visdom	wisdom	abstract	5	381	397
chock	shock	emotional	14	471	553
död	death	emotional	332	498	643
fest	party	emotional	41	596	430
framgång	success	emotional	92	443	467
förakt	contempt	emotional	18	364	597
fördel	advantage	emotional	121	292	283
glädje	joy	emotional	86	533	613
hat	hatred	emotional	16	417	650
humor	humour	emotional	24	462	497
ilska	anger	emotional	17	488	597
kaos	chaos	emotional	18	464	520
krig	war	emotional	131	551	593
kris	chrisis	emotional	55	375	597
kärlek	love	emotional	117	569	660
liv	life	emotional	685	482	517
lust	lust	emotional	43	444	563
lycka	luck	emotional	51	533	637
längtan	yearning	emotional	35	368	607
lättnad	relief	emotional	14	432	530
mod	courage	emotional	26	440	540
oro	worry	emotional	58	422	583
problem	problem	emotional	474	411	443
sjukdom	disease	emotional	140	487	510
skada	harm	emotional	140	443	423
skam	shame	emotional	22	419	593
skräck	horror	emotional	23	545	630

sorg	sorrow	emotional	51	429	643
spänning	excitement	emotional	49	452	553
tröst	comfort	emotional	22	421	530
vänskap	friendship	emotional	14	535	577

Appendix 4: Instructions

Swedish
Du kommer att få lyssna på riktiga ord och låtsasord som presenteras samtidigt. Det kan ibland vara svårt att höra de riktiga orden, men det finns ett riktigt ord med i alla ljud som spelas upp.

Din uppgift är att urskilja de riktiga orden och bedöma om de är konkreta eller abstrakta. Konkreta ord är saker man kan se och ta på, abstrakta ord är tvärtom inte synbara och påtagliga. Gör dina bedömningar baserat på ditt första intryck och svara så snabbt som möjligt. Tryck "K" om ordet du hör är konkret och "A" om det är abstrakt. Försök svara även om du inte är helt säker. Om du inte svarar fortsätter experimentet automatiskt till nästa ord.

Innan det riktiga experimentet får du prova med några övningsexempel. Tryck på valfri tangent för att börja.

English translation
You will listen to real words and pretend words which are presented simultaneously. It may sometimes be difficult to hear the real words, but there is a real word in every sound that is played.

Your task is to distinguish the real words and decide if they are concrete or abstract. Concrete words are things you can see and touch, abstract words, in contrast, are not visible or tangible. Make your decisions based on your first impression and respond as quickly as possible. Press ”K” if the word you hear is concrete and ”A” if it is abstract. Try to respond even if you are not entirely certain. If you do not respond, the experiment automatically moves on to the next word.

Before the real experiment starts, you will be given some practice examples. Press any key to start.

Appendix 5: Edinburgh Handedness Scale (revised)

Edinburgh Handedness Inventory (revised)					
Please mark the alternative describing best which hand you would use for each activity					
	Always left	Normally left	No preference	Normally right	Always right
1. Write					
2. Draw					
3. Throw					
4. Scissors					
5. Toothbrush					
6. Knife (without fork)					
7. Spoon					
8. Match (when lighting)					
9. Broom (upper hand)					
10. Open can (lid)					

11. Do you see yourself as right-handed left-handed