Extending SNARC to Age Judgments

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Abstract

A magnitude by side of response effect known as the Spatial Numerical Association of Response Codes (SNARC) effect was discovered in a magnitude-irrelevant parity judgment task (Dehaene, Bossini, & Giraux, 1993). The speed of response for relatively small numbers was faster for the left hand than the right, whereas, the speed of response for relatively large numbers was faster for the right hand than the left. To extend this finding experiments were conducted to determine whether photographs of people's faces could automatically activate the numerical age of the individual thereby eliciting the SNARC effect. A comparative judgment task asking which of two faces was younger (or older) found a partial instruction-dependent reverse SNARC effect for the "Younger" instruction, but not for the "Older" instruction. A true-false task matching label to face did not find SNARC. Photographs of faces did not automatically access either age numbers or age order.

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Using SNARC to Uncover Subjective Age Judgment Strategies

We are born symmetric. Our two ears and two eyes give us the ability to locate, within the space around us, the threatening mosquito or the incoming fly ball. The signals from such physical stimuli are readily interpreted and suitable responses are planned and acted upon: in this case, slapping the mosquito or catching the ball in motion. We have the physical need as well as the ability to operate on the world around us, and we should consequently have a bias to thinking in terms of space.

But do we do more than simply perceive and react to the world around us? Do we instead maintain an internal map of that world and, if we do, what type of representation can it be? This search for the locus of reality and its interpretation is not new. Plato thought in terms of mind defining Man; that our physical world is a relative thing that is made up of Forms and the viewer's opinions or thoughts. Aristotle, on the other hand, was an empiricist who believed more in measurement and concrete existence (Leahey, 1987). These types of debates and studies on such topics have been going on for a long time. However, it is intriguing to note how, in more recent research, these two conflicting extremes are sometimes manifested in some form of compromise.

Evidence for an internalized representation of our physical world is found in the research done by Moyer and Landauer (1967). Their findings showed that the greater the numerical distance between two numbers in a comparison task, the quicker the participants' response. For example, it takes less time to respond to the question " is 5 less than 20" than "is 5 less than 7". If the numbers and their relationships had simply been drawn out of long-term memory there should not have been any difference in the time to respond. Rather, the result implied a possible internal representation of a number line. The closer the numbers, the more difficulty participants had discriminating between them, increasing response times. For numbers more widely separated, the task was easier and accomplished more quickly.

This effect is not made up of equal intervals; it has been found by some to be defined by a log function, which indicated that the number line was actually compressive in nature (Dehaene, Dupoux, & Mehler, 1990; Hinrichs, Yurko, & Hu, 1981). It is also generally found in experiments measuring attribute differences as well, such as comparing age of music styles (Dalla Bella & Peretz, 2005), animal ferocity (Amrhein, McDaniel, & Waddill, 2002), and animal size (Thompson, 2000). In general then, as the relevant attribute difference increases between two judged objects, the time to decide between them decreases. Though the Distance Effect is indicative, it is not a proof, of an internalized representation of the world around us.

SNARC is found

Better evidence for an internal representation of the number line came about when a side of response by magnitude effect was uncovered in a series of nine experiments. The initial task was to respond whether the presented number was odd or even. The "odd" response keys were assigned to the left side of the keyboard for one half of the trials, and to the right side for the other half. Using the difference between left side and right side reaction times (RT) for the same stimulus, participants were faster when either responding with the left hand to a small number or the right hand to a large number (Dehaene, Bossini, & Giraux, 1993). Conversely, RT was slower both for the left hand when responding to a large number, and for the right hand when responding to a small number. This *cross-over effect* was explained as the result of processing occurring on a mental number line with numbers increasing from left to right. Dehaene et al. (1993) noted a number of features of this Spatial Numerical Association of Response Codes (SNARC) effect. To summarize the findings, this effect was relative in nature, followed the same direction as the writing in the maternal language of the participant, was not affected by handedness, seemed to be independent of hemispheric advantage, was not influenced by the graphic presentation of the digits, and seemed to be motivated by the magnitude rather than the ordinal information of the digits (though this latter finding was later challenged).

In Experiment 3, arguably the most important experiment of the 1993 paper, two sets of numbers, 0 – 5 and 4 – 9, were used in a parity odd/even judgment task with the odd and even response sides being counterbalanced. It is important to note that the digits 4 and 5 were included in both stimuli sets. This arrangement resulted in these two numbers being treated as large within the first set of numbers and small in the second. The RT results for 4 and 5 were faster for the right hand when the two numbers were considered large, and faster for the left when they were considered small. The same numbers were being treated differently dependent on the context of their magnitude.

This "side of response by number magnitude" interaction provided evidence for an internalized analog representation of the number line, as defined by the number set being presented. These findings supported those of Moyer and Landauer (1967) with respect to relationships between numbers not being directly recalled from long-term memory. Curiously, the average RT for zero did not follow the same pattern as the rest of the numbers; instead the mean RT deviated farthest from the fitted regression line suggesting that zero may have special properties. After all, zero was added to the number line well after the creation of whole numbers.

Experiment 4 used letters of the alphabet to further refine whether magnitude or ordinal position motivated the effect. Letters, like numbers, are often presented as a linear series, from A to Z in elementary classrooms. We often recite the alphabet to find an entry in a dictionary. No SNARC effect was found, though, negating ordinal position and supporting magnitude as the chief factor in the effect.

In Experiment 6, participants responded using crossed hands to determine if SNARC was a result of hemispheric advantage, an idea originally put forward by Poffenberger (1912). If inter-hemispheric communication was not needed to perceive and perform a task, and decision and action arose out of the same hemisphere, there would logically be a speed advantage. By crossing the hands, this advantage would then have been reversed. However, the SNARC effect was not reversed, but rather was increased.

Experiment 7 tested the influence of direction of writing using Iranian students whose writing flows right to left. It was found that those students who had been away from their mother tongue the least had a mild reverse SNARC effect. It should be noted that when writing in Iranian, the letters read from right to left, but numbers flow left to right – decades then units. This possible confound was avoided in stimulus presentation as only single digit numbers were presented.

How do we process numbers?

Of importance in the Dehaene et al. (1993) paper was the architecture behind number processing. This architecture, or framework, would allow for both explanations and predictions of the cognitive process involved in numerical tasks of judging both parity and magnitude.

A traditional approach to understanding how healthy people might process information has been to observe individuals with cognitive deficits, be they acquired or congenital. One argument for this line of research is that damage to a discrete part of the brain resulting in a loss of a skill helps locate where that skill might be processed, or at the very least, a disruption of a neural pathway for that skill. For example, acquired dyscalculia is the loss of a once held ability to do arithmetic. McCloskey (1992), using acquired dyscalculia case studies, hypothesised a number-processing model. Within this model, originally derived by McCloskey, Caramazza, and Basili (1985), both verbal and Arabic numbers are first translated into an abstract representation, each mode having a dedicated module. The abstract representation is then used in processing the task (e.g., magnitude comparison task).

Noel and Seron (1993) found limitations in the McCloskey model, as it could not adequately explain their single case study of an individual with an Arabic numeral reading deficit. This finding led to the Preferred Entry-Code Hypothesis. McCloskey's (1992) abstract representation was dropped for this model. In its place, the verbal and visual input modes were directly transposed into the individual's preferred mode; verbal and visual inputs were either transcoded as verbal, or visual, and then used in processing the task (e.g., judging parity).

Campbell and Clark (1988) took aim at another McCloskey (1992) model predecessor the McCloskey, Sokol, and Goodman (1986) model. They argued that the McCloskey model was too simple, that the task process was much more complicated. They suggested that the Arabic and verbal inputs were directly associated with the task to be done (e.g., parity or magnitude).

Dehaene et al. (1993) argued that the Campbell and Clark (1988) encoding complex view was so general that it could indeed account for the aforementioned models, but it would have been difficult to generate predictions on the tasks Dehaene et al. (1993) were conducting on parity. In the Dehaene Triple Code model, verbal representation could access magnitude representation either directly or via transcoding through Arabic representation. But to access parity, the verbal representation would necessarily need to be transcoded into the Arabic representation first. On the other hand, the Arabic representation could access both magnitude and parity directly. This nicely underscored a difference between visual and auditory systems.

A lovely visual summary of the four models is presented in Figure 1 (p. 373) of the Dehaene et al. (1993) paper. The major differences between the models, aside from whether there is transcoding of stimulus inputs into an abstract representation, are the pathways and their inherent blockages or bottlenecks.

Is SNARC an artefact of a Simon, MARC (Lexical Markedness), or semantic congruity effect?

The Simon effect is an RT facilitation wherein side of response and side of chosen stimulus are the same but are task irrelevant. For example, when comparing two numbers and choosing which is larger, if the chosen target and the button to press are on the same side (i.e., both to the right, or both to the left) there is a faster response. Yet this has nothing to do with the magnitude of the numbers.

To test the relationship between the Simon and the SNARC effects, participants were asked to judge the parity of presented numbers, but instead of projecting the number in the center of the screen as was usually done, the numbers appeared to the left or right of the center (Mapelli et al., 2003). This 'side of screen' presentation allowed for parallel investigation of both the Simon and the SNARC effect. Looking at the results for congruent and incongruent conditions, Experiment 1 used the determination of the number's parity as the task. The data was divided into two sets, slower RTs and faster RTs. Analyses were then done that looked at side of presentation by side of response by RT for Simon, and magnitude by side of response by RT for SNARC. The Simon effect was present for faster RTs, but vanished for slower RTs, whereas the SNARC effect was present and unaffected by different RT lengths. In Experiment 2, the task was made more difficult so as to increase the time it would take to make a judgment. In this case, a reverse Simon effect was attained for congruent and incongruent conditions, while no change was seen in the relationship for the SNARC effect between the two conditions. These experiments showed that there was no interaction between the two effects, that they were additive, and most importantly, that Simon and the SNARC effect are not one and the same.

Linguistic markedness of response codes (MARC) is a language appropriate/frequency effect. Some words are used more often and more correctly than their antonyms in certain contexts. For example, the question "how *old* is she" is not age specific and can be used for all ages. The question "how *young* is she" implies that the object of the question is a young person and would sound unusual if used in reference to an elder (Hines, 1990). Thus, it was conjectured that the word 'old' would have some processing advantage over the word 'young' when age comparison tasks must be done. The relationship between the MARC effect and the SNARC effect was explored using a parity judgment task across four types of stimuli presentation in four separate blocks: positive Arabic numerals, negative Arabic numerals, word numbers (in German), and numbers in Roman numerals (Nuerk, Iversen, & Willmes, 2004). Odd and left instructions are considered to be linguistically marked, or to have a slower response time, whereas even and right are considered linguistically unmarked with a faster response time. Different MARC and SNARC effects were found, indicating that the two effects are not one and the same (Nuerk, Iversen, & Willmes, 2004).

The semantic congruity effect is one in which there is a language-primed expectation within the instruction. As will be described in the next section, in the Shaki and Petrusic (2005) criticism of the Fischer (2003a) paper on negative numbers, a major concern was the confusion between semantic congruity effects and the SNARC effect. Though there is facilitation and inhibition within both effects, the mechanisms are different. The semantic congruity effect occurs when it is easier to respond "smaller" when the two numbers in a comparison task are both small and, conversely, to respond "larger" when both numbers being compared are large. However, RT is slowed when the semantics are not congruent, that is, when asking for the “larger” of two small numbers. The language of the instruction powers the semantic congruity effect.

Finally, a short explanation is necessary of this type of cross-over effect, which has already been mentioned, and will be referred to again. In a paper reporting the results of an experiment on discrimination of luminance, it was found that RTs were faster when deciding between two bright light patches when the instruction was “choose the lighter” and slower when the instruction was “choose the darker”. When the light patches were dark, the instruction “choose the darker” this time facilitated the response, and the instruction “choose the lighter” resulted in a slower response (see Figure 1). This counter-balanced research design was then repeated using a pitch discrimination task with the same crossover effect being perceived (Audley & Wallis, 1964; Wallis & Audley, 1964).

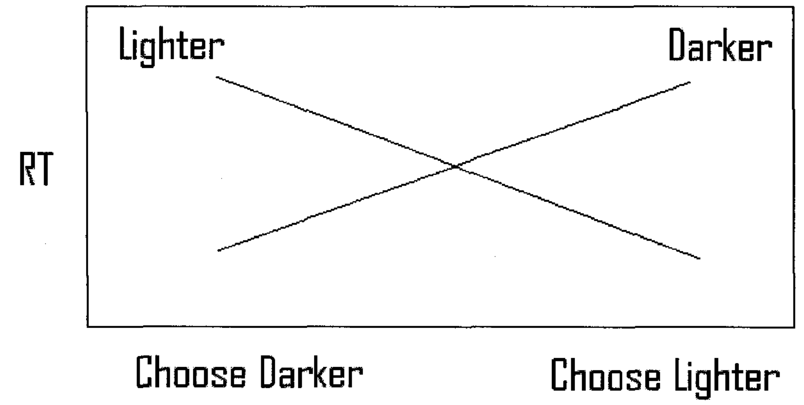

Figure 1. An example of the cross-over effect in a luminance discrimination task

SNARC extended, other concerns addressed

Experiments that use foot pedals, track saccadic eye movements, or require finger pointing to record responses, as opposed to the usual manual button pushes, have also shown the SNARC effect (Fischer, 2003b; Schwarz & Keus, 2004; Schwarz & Müller, 2006). Each addressed the concern that the SNARC effect may simply arise from habit. On a keyboard, for example, the number 1 is usually typed with the left hand and 9 typed with the right. Also, the problematic zero is located on the right, as opposed to its number line position on the left. Schwarz and Keus (2004) described an experiment that replaced the usual keyboard task. Two white boxes, each assigned odd or even, were displayed on the screen bracketing the target number. The participant, after judging the target number, was to shift eye focus onto the correct box. If the SNARC effect was an artefact of manual habit then the SNARC effect for eye movements should be either reduced or non-existent as compared to the manual response. However, this was not found to be the case. The same SNARC effect was found, though the RTs were slower. Schwarz and Müller (2006) replicated this effect with foot pedal responses instead of keys. Again, the SNARC effect was found.

Nuerk, Wood, and Willmes (2005) extended this research and determined that the method of presentation, whether auditory or visual, was not the source of the SNARC effect. Five sets of stimuli were presented to each participant: Arabic numerals, auditory and visual number words, Roman numerals, and visual dice patterns. All five resulted in SNARC effects. Thus, the SNARC effect appeared in both auditory and visual perception modes.

Deaf students also reacted in the same manner as hearing students to visual stimuli, although the deaf were slower in making comparative judgments (Bull, Marschark, & Blatto-Vallee, 2005). As the SNARC effect is explained as a visualization of the mental number line, it does seem reasonable that the results should extend to non-hearing students. But is there a mental number line for those who cannot see? At this time there have been no known SNARC experiments conducted on the blind. As the effect has been found to be amodal for auditory and visual presentations, the question arises whether using the blind participants with auditory stimuli alone would achieve similar results. Another possible question would be whether or not the SNARC effect would extend to brail.

In contrast to the original Dehaene et al. (1993) Experiment 4 finding that the SNARC effect was not found for alphabet stimuli, Gevers, Reynvoet, and Fias (2003) redesigned the alphabet experiment, and added a calendar task. Two conditions applied: ordinal relevant (for months: before or after July; for letters: before or after O) and ordinal irrelevant (for months: whether the letter r is at the end of the word, and for letters: consonant or vowel). Within this design, the SNARC effect was found to exist under both conditions for both months and letters. Could it be that this effect is more than Magnitude and includes Ordinality? The number line is a visual representation of magnitude, and inherent within that is order.

Bächtold, Baumüller, and Brugger (1998) used two visual representations: a straight line (ruler), and a circle (clock face). Half of the participants saw the presented number as a linear measurement, (e.g., 2cm) while the other half of the participants saw the number as a measure of time (e.g., 11 o'clock). After the learning phase, the visual cues of clock or ruler were removed and a single number was displayed in the middle of the screen. The task was to decide whether the time or the distance was before or after 6. In the ruler-trained condition, the expected SNARC effect was found. The clock trained condition results showed a reversed SNARC effect, where the pairing of right hand to large number and left hand to small was reversed and the RT advantage became right hand with small and left hand with large numbers.

Hemineglect or representational neglect's symptom is spatial inattention or unawareness. As the SNARC effect is a function of spatial awareness Bächtold et al. (1998) proposed that the Clock and Ruler tasks could be a helpful diagnostic tool. The SNARC effect arising from them could be used as a standardized and repeatable measure of the degree of brain damage an individual might have suffered.

Another question about the SNARC effect is whether the number line extends past nine or whether the findings are isolated to single digit numbers. Although not a direct experiment on the SNARC effect, Fitousi and Algom (2006) found that a *size congruity effect* was found across the range of the number stimuli 1 – 98, thus including single and double digit numbers. This possibility becomes important for research with Iranians who read right to left, whereas numbers are written as in English with decades then units rather than units then decades, as might have been supposed. This gives warning that extensions of SNARC research into two digits in Farsi might then be confounded.

If the SNARC effect extends along the positive number line, does it also appear with negative numbers? One argument is that negative numbers are a manufactured concept, and are viewed as positive numbers with an arbitrary sign in front. This is a phylogenetic view. The ontogenetic view on the other hand asserts that the negative number line is learned and is represented in analog form within our minds. In cold weather climates, children learn early on that negative numbers have a physical reality. In cold countries that use the Celsius scale as opposed to Fahrenheit, negatives are experienced more often (-1^0C versus $+31^0$F). Using mercury thermometers as opposed to digital readouts people will have greater experience with a spatial representation of temperature.

Fischer (2003a) tried to determine whether negative numbers were treated as coming from a previously learned negative number line (the ontogenetic hypothesis) or if they followed the phylogenetic hypothesis. Four categories of stimuli were created using pairs of single digit numbers. The four stimuli categories were the result of a matrix of possibilities, as can be seen in Table 1, varying congruency (congruent, noncongruent), and magnitude type (absolute magnitudes, numerical magnitudes). As a comparative judgment task, the participant was to "press the button near the larger/smaller number" (p. 280, Fischer, 2003a). The comparison combination response times for "numerical value x congruent and absolute value x incongruent" were faster by close to 50 ms than "numerical value x incongruent and absolute value x congruent" Since the negative number line was implicit in "numerical value", and the numerical value x congruency condition had the faster response time, Fischer concluded that the ontogenetic hypothesis was thus supported.

Table 1. Examples of the number pairs used in the Fischer (2003) comparison judgment task. Congruency is based on the negative and positive number line for the numerical value, but only on the positive number line for the absolute value.

	Magnitude	
Spatial property	numerical value	absolute value
congruent	(4, 9) (-9, -4)	(-4, -9) (4, 9)
non-congruent	(9, 4) (-4, -9)	(-9, -4) (9, 4)

However, Shaki and Petrusic (2005) noted that the Fischer (2003) RT was actually slower for the positive number pairs. Further, the results showed a reverse SNARC effect for the positive number pair when incongruent. As to why Fischer achieved the results he did, Shaki and Petrusic (2005) give an excellent, or as they write, "albeit speculative" (p. 936), explanation using semantic coding theory (Banks, Fujii, & Kayra-Stuart, 1976). Within this theory, sizes or digits are coded relatively. For example, within the context of this experiment numbers could be coded SMALL or LARGE. For two small numbers, both would need to be coded SMALL but one would be smaller than the other. To denote this, the smallest would be SMALL++ and the other SMALL+. Two large numbers would then be coded LARGE in a similar manner. The complication comes in when the numbers themselves are not congruent with the language, such as asking which of the two large numbers is smaller. Shaki and Petrusic (2005) demonstrated that the results reported in (Fischer, 2003a) could be explained as a result of semantic congruity effects rather than SNARC effects.

The SNARC effect is calculated as the difference between the RTs for right and left hand dependent on the magnitude of the stimulus. When reading direction is left to right the difference should be positive for small numbers and negative for large numbers. When the calculations result in a difference that is negative for small numbers and positive for large this is referred to as a reverse SNARC.

Another experiment that looked at negative numbers using a parity judgment task did not find a reverse SNARC effect (Nuerk et al., 2004). They did, though, claim a marginal SNARC effect $p = .07$. However, Shaki and Petrusic (2005) explained that this lack of reversal was to be expected as the polarity of the number could be ignored in determining whether the number was odd or even. Again, it was shown that parity judgments were not conducive to studying a reverse SNARC effect.

A comparative judgment task was also used but this time using two types of presentations (Shaki & Petrusic, 2005). The first was the oft-used block design wherein positive numbers were presented in one block, and negative numbers were presented in a separate block. The second approach intermixed the presentation of both positive and negative numbers. A regular SNARC effect was found in both the block design under the positive numbers only condition, and the intermixed presentation. In the block design under the negative numbers only condition a reversed SNARC effect was found. This finding clearly demonstrated that different strategies were being employed. In the block design polarity was not relevant. There was no point in referencing an internal, more labour intensive, negative number line. In the intermixed design, a context was provided, and a single, longer number line was referenced that included both positive and negative numbers.

An excellent paper on language-culture interactions on SNARC investigated monoliterates, biliterates, and illiterates amongst both Arabic and English speakers, finding a reverse SNARC effect directly attributable to writing and reading direction (Zebian, 2005). Further, it was found that in biliterates the size of the SNARC effect was related to the number of years of experience in the second language. This finding supported the analysis of Experiment 7 of the original Dehaene et al. (1993) paper. Native Arabic monoliterate speakers whose writing was right to left showed a reverse SNARC effect as compared to English left to right. Interestingly, those individuals who could recognize numbers but who were illiterate did not show a SNARC effect. In other words, their responses to the instructions showed no systematic spatial bias. Taken together, these three findings showed that the SNARC effect, what Zebian called a cultural artefact of writing, could also be thought of as an artefact of literacy.

Maass and Russo (2003) investigated how groups of people from different cultures visualized actions and subjects differently. In Experiment 1, participants were read short sentences that contained a subject and an object, and were then instructed to draw representative images. Italians placed the subject of the sentence to the left, while Arabs placed the subject to the right. However, biculturally influenced Arabs showed no bias to either side. In Experiment 2, the procedure was changed and after hearing the same sentences, rather than asking the participants to draw an image, they were presented with an image with object and subject on differing sides and asked if the image did or did not correspond to the sentence. Arabic and Italian participants' speed of response was opposite for side of image presentation. These findings suggested that the way people visualize the world is influenced by "both hemispheric specialization and scanning habit" (p.296).

In another paper looking at directionality of response, Tversky, Kugelmass, and Winter (1991) used a graphic technique wherein children responded by placing stickers on paper. Working with Arabic, Hebrew, and English children in California and in Jerusalem, it was found that temporal judgment directionality was influenced by language. For example, ordinal representations of breakfast, lunch, and supper depended on the written language. For quantity and quality all three groups' responses followed the same pattern, an increase rising from bottom to top.

Japanese write both left to right and top to bottom. Within this culture's writing direction Ito and Hatta (2004) confirmed a vertical SNARC effect. In Experiments 1 and 2 (a and b), a parity judgment task was employed. Experiment 1 used the right and left keys of the keyboard and, as expected, found a left to right SNARC. Experiment 2 used keys at the top and bottom of the keyboard with small numbers relating to the bottom and large numbers relating to the top. This could be expected to be in contrast with the writing direction, which is top – down. In spite of these different directions, a reverse SNARC effect did not occur contrary to what would be expected if the strongest influence were writing direction. This bottom up finding is certainly in compliance with the Tversky et al. (1991) finding. Could it be that such experiences as filling a glass with water (less water resulting in a lower level and vice versa) trumps the influence of writing direction?

Experiment 3 used quantity directly but failed to achieve SNARC. The task was to determine if the presented number was smaller or larger than 5. This was not in agreement with the Dehaene et al. (1993) explanation that the SNARC effect depends on the ordinal or spatial information of the quantities being processed. The researchers suggested that it might be possible to separate this quantitative representation from the spatial code. They also reported that recent neuroscience research had shown that quantity and parity are actually processed in different substrates of the brain (p. 663).

But where is the SNARC effect occurring?

A number of papers and much effort have gone into trying to locate where the SNARC effect originates. Is it in the perception stage? As earlier stated, there appeared to be no difference in results when the task and the mode of the task were changed. If it were in the perceptual stage, the effect would need to occur in both auditory and visual domains. Or could it be the response stage itself, a function of learned writing skills? Again a number of response methods were used: saccadic, pedal, and manual. All resulted in similar SNARC results.

Otten, Sudevan, Logan, and Coles (1996) ran odd/even parity versus hi/low magnitude judgment tasks and recorded event-related brain potentials. They found that magnitude and parity decisions interfered with each other and that this interference occurred at the level of response processing.

Simon and SNARC are similar, and both appear to occur in the same stage. Mapelli et al. (2003) had used the logic of the Additive Factors Model (Sternberg, 1969), which states that if the results were additive then the two effects must affect different stages or phases of processing, whereas if they were interactive then they must share some of the same processing resources. Mapelli et al. (2003) had found the two to be additive, and as such concluded that Simon and SNARC effects arose from different processing stages.

However, it was determined that there was an interaction between the Simon and SNARC effects that was dependent on whether the magnitude codes were relevant or irrelevant to the tasks, as in a magnitude comparison task (relevant) versus a parity judgment task (irrelevant); (Gevers, Caessens, & Fias, 2005; Keus & Schwarz, 2005). This addition of a third factor violated the Additive Factors Model. Gevers et al. (2005) suggested a temporal overlap model for Simon and SNARC effects. When RTs were fast there was interference due to the irrelevant attribute. When the task took more time the irrelevant attribute faded away and could not interfere. Thus Simon and SNARC appear to follow different pathways and only share resources at the response selection phase. This overlap model nicely explained why the Simon effect disappeared, or even reversed, when RT increased while SNARC continued unaffected.

Hence, researchers have honed in on the response selection phase as the source of the SNARC effect with evidence converging from cognitive research and neuroscience supporting this hypothesis (Gevers, Ratinckx, De Baene, & Fias, 2006; Keus & Schwarz, 2005; Keus, Jenks, & Schwarz, 2005; Otten et al., 1996).

SNARC, some interesting possibilities

The SNARC effect has been found to be strong evidence of a mental number line that is compressive in nature, and is a measure of order and magnitude (Fias, Brysbaert, Geypens, & d'Ydewalle, 1996; Gevers et al., 2003). It has also been used as a tool to evaluate what goes on in the brain, as in the suggested measure of hemineglect. Fias, Lauwereyns, and Lammertyn (2001) used the SNARC effect as a measurement tool in experiments on feature-based attention. In a sequence of five experiments, it was found that orientation of a shape superimposed over an irrelevant number (triangle pointing up or down; line oriented vertically or horizontally) resulted in a SNARC effect whereas the colour of a number or the kind of shape overlaid on a number (red or green; circle or square) did not. These results might have arisen because colour and shape are not processed in the parietal region of the brain but shape orientation and magnitude are. As interference is stronger when resources are shared, then a SNARC effect is more likely to be found for tasks requiring activation of the parietal lobe.

Walsh (2003) put forward a theory of magnitude (ATOM) that incorporates time, quantity, and space. This theory is based on the co-locality of the matching processing components in the right parietal and right pre-frontal cortex, and suggests interrelatedness is due to proximity. Of importance here is the idea that magnitude determination is physically located within these areas, as opposed to number knowledge and math which seem to be language driven and thus in the left hemisphere.

This hemispheric location of magnitude and space has been verified by transcranial magnetic stimulation. By moving a powerful magnet over the head in the area of the parietal lobe, it was possible to have a participant mimic hemispheric neglect in a line bisection task. The line bisect could be systematically biased either towards the left or right of center (Göbel, Calabria, Farnè, & Rossetti, 2006).

An interesting side bar to the SNARC effect is research on "digit ratio" which shows an interaction between our bodies and a measured result. Digits refer to the fingers on our hands. Digit ratio is defined as "the ratio between the second and fourth digit lengths" (p.194; Bull & Benson, 2006). The lower the ratio, the more masculine the individual and the higher or stronger the SNARC effect. This finding was confirmed even when controlling for gender, both between and within gender groups. Of note is the observation that SNARC is found in both groups and across all levels of masculinity. Frivolously I might suppose that, besides striving for power within the experimental design, one should accept as many men as possible for the experiment itself.

The exploration of psychological age

But does this magnitude and ordinal effect extend past dice, aural number presentation, calendars, clocks, and alphabets? Could it be influenced by perceived age? Age is a curious concept. It is at once something subjective, and objective; how old do we feel and how old are we. How do we determine another person's age if we do not have access to official records? We would most likely look at the face, the person's size, hair colour, type of clothing, and smoothness of skin. Then we could estimate by comparing them directly to other people we have encountered such as aunts, nephews, siblings, and friends. Alternatively, we might have categories based on features alone in that, say, a person with grey hair and facial wrinkles would be considered old. Moreover, do we apply a numerical age to a person or do we place them in a category such as teenager, middle aged, or elder? It may be that numbers are not used unless triggered by a specific question such as "how old do you think he is?"

In one line of research, for her M.A. thesis Oakley-McKeen (1992) investigated a possible theory of psychological age utilising the principles of psychophysics. Drawing from the findings of (Audley & Wallis, 1964) who found a crossover effect when the order of instructions was counter-balanced, Oakley-McKeen (1992) looked at the point of intersection of the two lines as a possible objective measure of an individual's subjective determination of age. The point of intersection (within the crossover of two lines) had already been found to be flexible, that is to say not fixed at the center of the range of stimuli (Petrusic & Baranski, 1989). The task used was to look at pairs of faces and judge which of the two was either older or younger, depending on the instruction.

But where in the brain does a face become a face? Kanwisher (2000) suggested that the evidence points to a specialized face recognition centre that develops expertise. Prosopagnosia, the inability to recognize a once remembered face while retaining the ability to recognize objects, is a neuropsychological debility arising from injury to the right fusiform gyrus in the temporal lobe of the brain. This condition, in conjunction with damage to a specific location, is a strong indicator of a specialized face recognition centre. In research with prosopagnosic participants, it was found that they were better able to recognise new objects than new faces while they performed poorly in the old/new face recognition tasks.

In an experiment scanning experts in car and bird recognition with functional magnetic resonance imaging, it was found that the fusiform face area, more specifically the fusiform gyrus, was activated (Gauthier, Skudlarski, Gore, & Anderson, 2000). The face area appears to be both categorical and expertise driven. Hence, the research on prosopagnosia and on expertise gives further evidence of a specialized face recognition centre.

This expertise centre may have limitations. Unfamiliar faces are not as easily recognised. Small changes such as lighting and hats can interfere with recognition (Hancock, Bruce, & Burton, 2000). It appears that expertise is akin to a practice effect whereby accuracy increases with experience with the particular stimulus. For example, we see a friend from a number of angles, in many types of lighting, wearing different head coverings, and in different moods, effectively becoming an expert on the face of that particular friend.

Another influence on face recognition is race. This difficulty to recognise faces from a race with which one has little or no experience is called an *own-race bias*. For example, in an experiment to determine if people perceived faces holistically or by features it was found that Caucasians could use features to recognise other Caucasians but could not do so for Asians. Those Asians who had more experience living with the Caucasians were better able to recognise the faces of both groups. However, both Caucasians and Asians performed poorly when asked to recognise people of the other racial group (Michel, Caldara, & Rossion, 2006).

A meta-analysis by Meissner and Brigham (2001) also looked at the own-race bias for faces. It was determined again that people recalled same-race better than other-race faces (more hits), and made more mistakes (false alarms) remembering other-race than same-race faces.

But is it important to be able to recognise faces to be able to determine ages? People seem to remember faces holistically. It is more difficult to remember faces when they can only use features (Michel et al., 2006). Bringing together the idea of bad memory for unfamiliar faces, and a preference for holistic over feature based processing suggests that there may well be difficulty in estimating the age of unfamiliar faces.

SNARC and age

The SNARC effect is seen in processing ordinal information such as numbers and calendars. In many of the previously mentioned papers magnitude was a task irrelevant factor. Somehow this irrelevant factor managed to effect the response time. Age is also comprised of a magnitude and is ordinal in nature running from young to old. In an effort to both extend the SNARC effect into age research and to answer questions concerning how we process age, a comparison-judgment task will be conducted.

When we make age comparisons, are we using examples from our experience? Or are we keying in on physical features? Do we use numbers? Age is certainly linear. There have been illustrations and posters of humans developing from baby to elder sequentially. However these illustrations do not have the frequency and omnipresence of the number line or alphabet in elementary schools. We rarely see photographs of people in order of age in the same way we see a number line. For example, although photo albums do have a progressive nature with people aging over time, family photographs usually have the people clustered without any order besides that of convenience and height.

Another line of questioning asks where the age estimation takes place and how. Recall the finding of Fias et al. (2001) that when decisions were processed in areas other than the parietal lobe, which is connected to magnitude and time processing, there was no SNARC effect. In other words, is a face more like the square or the orientation of the triangle?

Do we look at features of the face and judge someone's age based on experience and exemplars, or do we estimate age? Decisions based on the features appear to be easily confounded. As this is the case, photo sets with high levels of inter-rater agreement must be generated. To do this Oakley-McKeen (1992) used a small group of participants to help generate the comparison set by sorting a large number of photos of faces into seven categories and ordering them by age. Those photos of faces, which received the highest levels of agreement between these participants, were then used to manufacture the comparison pair stimuli. Absolute ages in years might be as presented in Table 2.

Table 2.

Estimated midpoint ages in years for seven categories

Baby	Child	Youth	Adolescent	Young Adult	Middle Age	Elder
.5	2	10	16	25	40	70

To examine if a SNARC effect exists in age comparisons, the Oakley-McKeen (1992) procedure was followed in a second phase with a new group of participants. In this experiment, participants were asked to take part in a comparison judgment task with pairs of faces that are one category apart.

Expectations and predictions

If the age of each face is estimated when making Older/Younger comparisons, then magnitude is being accessed and the SNARC effect should occur. Or, if the facial comparison is accomplished by matching the faces in the photos to past experiences with a wide variety of people such as aunts, nephews, and grandparents, then there may be a magnitude indirectly attached to the example and again we should obtain the SNARC effect. If magnitude is not accessed, then it is feasible that the ordinal information is sufficient to result in the SNARC effect (Gevers et al., 2003). However, if judgments are made solely on the features of the faces, then neither magnitude nor order will be accessed and the SNARC effect will not be observed.

A semantic congruity effect should be seen for the instructions to choose older or younger interacting with the relative ages of the people in the photographs.

There is some argument that the middle years could be renamed the muddle years as the subjective age becomes confusable after adolescence and until elder. For muddle read errors. Thus it is expected that the middle year comparisons will be the most error prone.

Experiment 1

Method

Participants

Fifteen Carleton University students took part in the experiment in exchange for course credit. Their ages ranged from 18 to 37 with a median age of 19 years. The purpose of this experiment was to generate a stimulus set of faces, of differing ages across a set of seven age categories, with high inter-participant agreement that could be used in future experiments.

Apparatus and Stimuli

One hundred and fifty-five photographs of faces, male and female, of different racial and ethnic backgrounds, and of age categories ranging from babies to senior citizens, were printed in black and white on 3" x 5" index cards (Appendix I). The faces were cropped to include from the bottom of the chin to the top of the head, from outside ear to outside ear.

Design

The participants were first asked what their best age estimate, in years, would be for each category. They were then asked to sort the index cards (presented in random order), from youngest to oldest, into seven bins labelled Baby, Toddler, Youth, Adolescent, Young Adult, Middle Age, and Elder. The participants were unsupervised during the sorting. After each participant's session the cards were shuffled seven times to maintain a random presentation order.

Results

The mode and the median age estimates of the seven age categories by the participants were in close agreement (Table 3). To determine which photographs would be used as stimuli for the next two experiments, a cut-off of 11 of 15 (73%) was used.

Twenty-eight faces were chosen for the stimuli set, comprised of two male and two female faces from each of the seven categories. The faces chosen were from those with the highest rating of agreement among the participants. Age category agreement for the faces accepted for future experiments ranged from 11 of 15 to 15 of 15. Only one photograph of the twenty-eight chosen had the low end of inter-participant agreement of 11 of 15. Photographs of babies and elders selected for future experiments achieved 15 of 15, or perfect agreement.

Table 3.

Summary of descriptive statistics for explicit age of category estimations in years

statistic	baby	toddler	youth	adolescent	young adult	middle age	elder
median	1	3	11	15	23	37	50
mode	1	3	8	15	23	33[a]	40

a... multiple modes for middle age

Experiment 2

Method

Participants

Twenty-eight Carleton University students, nineteen females and eight males, plus one participant whose age and gender were not recorded, took part in the experiment in exchange for course credit. Their ages ranged from 18 – 27 years with a mean of 19.5 years of age.

Apparatus

A Pentium III computer, a standard KeyTronic keyboard and a Professional Series PF790 CRT monitor were used. The mouse was not used. The presentation of the stimuli was controlled and the results collected using Superlab version 2.0 software. All instructions and stimuli were centered on the screen. To respond, participants used two keyboard keys: A on the left side, and L on the right. All other keys were removed from the keyboard to avoid accidental key presses. A cardboard blank was used to highlight the used keys and mask the unused keys of the keyboard. This apparatus was also used for experiment 3.

Stimuli and Design

The set of twenty-eight faces generated from experiment 1 were used to create the stimuli set. There were two male and two female faces in each of the seven categories (Baby, Toddler, Youth, Adolescent, Young Adult, Middle Age, and Elder). Photographs were first adjusted so that they were of equal contrast, and so that the faces were of the same size. Combinations of face pairs were then constructed from adjacent age categories (baby-toddler, toddler-youth, youth-adolescent, adolescent-young adult, young adult-middle aged, middle aged-elder) resulting in six age comparison categories. Each stimulus then had a pair of faces with the instruction centered above (Appendix III).

The experiment was comprised of 2 instructions (younger or older), 6 categories (listed above), 4 faces paired to 4 faces in each category resulting in 16 unique face pair combinations, and two directions of face pair presentation, or 2x6x16x2, resulting in 384 stimulus combinations. With two blocks of the experiment (so as to increase reliability) the total number of decisions, excluding the initial practice trials, was 768.

Procedure

The participants were asked to turn off cell phones for the duration of the experiment. Each participant was seated approximately 80 cm from the monitor, with monitor at head height. The experimenter stayed in the room until the end of the practice trials to insure understanding of the task by the participant. The participant read the instructions, which appeared on the center of the screen. The participant was instructed to choose the face which best corresponded to the instruction, then press the key (A or L) on the same side as the chosen face. The participants were instructed to respond as quickly and as accurately as possible (Appendix II).

The single word instruction "Younger" or "Older" appeared on the center of the screen. After 750 ms the stimulus, chosen randomly from the block, appeared below the instruction. The instruction remained on the screen. The participant was to press the letter key that matched both the instruction and the position of stimulus presentation that answered the single word instruction. For example, if the face on the left side of the screen corresponded to the instruction then the correct response was to press the left or A key. The stimuli remained on the screen until the response, after which it was replaced by the next single word instruction. The task explanations were followed by a practice run of 10 trials. After the first block of trials, the participant was given a self-terminated rest break. The participant ended the rest break by typing any key, and the experiment continued. Block 2 was a replication of Block 1. The experiment, including instructions, practice run, and rest break, took approximately 40 minutes.

Results and Discussion

Data from three participants were excluded from the analysis because the three participants did not comply with the instructions. Results with RT below 200 ms or three standard deviations above the mean, calculated for each participant, were trimmed from the data selected for analysis. Responses faster than 200 ms do not represent judgment plus response, but rather just response time. Extreme values can disproportionately change the slope of a fitted regression line (Kutner, Nachtsheim, Neter & Li, 2005). For the 25 participants, a total of 19,200 responses were collected. Of these, 584 responses (3%) were removed from the analysis due to extreme values. After this removal there remained 17,365 correct and 1,251 error responses (7.2%). Category 4 (adolescent – young adult) accounted for 48.4% of the errors.

Participants' RTs improved on average between block 1 and block 2 by 17% for correct responses, $F(1,24) = 59.9$, $MSe = 862739$, $p < .001$. The total number of errors increased by 221 from block 1 to block 2, or 2% based on 9,600 responses per block. However, the increase in errors was not significant, $F(1,24) = 3.1$, $MSe = 255$, $p = .089$. The participants' error RTs improved between block 1 and block 2 with RT dropping on average by 23%, $F(1,24) = 24.97$, $MSe = 2098496$, $p < .001$. The comparable improvement in RT for error and correct responses, with no significant increase in the number of errors, is evidence that there was no speed-accuracy trade-off during the experiment.

Gender of participant was not used as a factor in the analysis. With 19 females and 5 males, the ratio of participants' gender exceeded the 1.5 to 1 ratio recommended by Stevens (2002) as a maximum ratio. All reported repeated measure analyses results used the Huynh-Feldt adjustment. The degrees of freedom reported are those determined by the experimental design.

Interaction effects

Three independent variables were analysed in a general linear model repeated measures ANOVA: Instruction (choose Younger or Older), Hand (right or left response on the keyboard), and Category (the adjacent age category pairings). The dependent variable was response time (RT). There was no significant three-way interaction of Instruction by Hand by Category, $F(5,24) = 1.360$, $MSe = 26333$, $p = .252$. Indeed no one of the orthogonal trend components was reliable.

Of the three two-way interactions, two were significant. Instruction by Category was significant $F(5,24) = 13.83$, $MSe = 264496$, $p < .001$. Hand by Category was also significant, $F(5,24) = 5.21$, $MSe = 103431$, $p < .001$. However Instruction by Hand was not significant $F(1,24) = 1.5$, $MSe = 37239$, $p = .226$.

Main effects

There was a significant main effect of Category, $F(5, 24) = 33.28$, $MSe = 1682015$, $p < .001$. Category 4 (adolescent-young adult) comparisons were slower than categories 1 (baby-toddler) and 6 (middle aged – elder) (Figure 2). The standard error bars for the mean RTs of categories 1, 2, 3 and 5 overlapped (Figure 2). Discriminating between adolescent and young adult faces resulted in not only an increased number of errors, but also increased decisional time.

There was also a main effect of Hand (the keys on the keyboard A and L corresponding to the hand that would be used). Overall, responses using the left hand were slower than responses using the right hand by approximately 41 ms, $F(1,24) = 9.66$, $MSe = 257398$, $p = .005$. This result would be expected if the majority of participants were right handed. However, handedness of participants was not recorded.

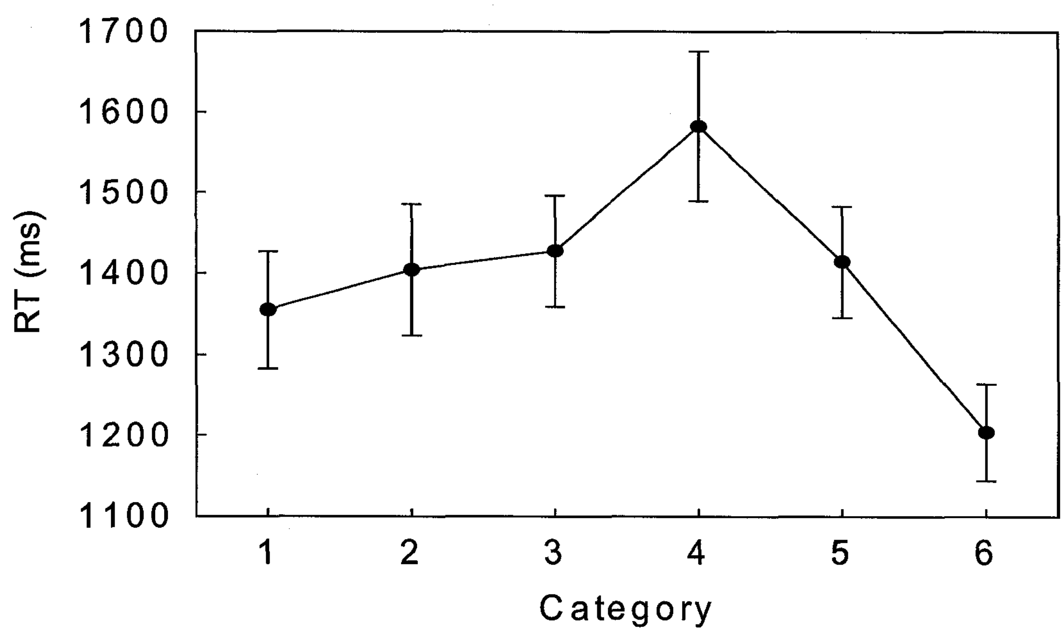

Figure 2. Aggregate mean RT for each Age comparison category (1 = baby-toddler, 2 = toddler-youth, 3 = youth-adolescent, 4 = adolescent-young adult, 5 = young adult-middle aged, 6 = middle aged-elder). The bars represent standard errors.

Semantic Congruity Effect

As already stated, there was a significant interaction of Instruction by Category. In Figure 3 the pattern seen in Figure 2 for the aggregated RT means was preserved even when the means were graphed separately by instruction. The RTs for the instruction "choose older" were slower than "choose younger" for the younger categories and faster for the older categories, whereas, for the instruction "choose younger", the pattern was reversed. The difference between the RTs for the two instructions - the Semantic Congruity Effect Index - was calculated and graphed

(Figure 4). The Congruity Effect Index clearly shows a systematic relationship between Instruction and Category, $R^2 = .90$. The categories in this experiment were ordinal, starting with the youngest on the left and continuing to the oldest on the right. This replicates earlier findings on Semantic Congruity Effect (Audley & Wallis, 1964; Petrusic & Baranski, 1989; Wallis & Audley, 1964).

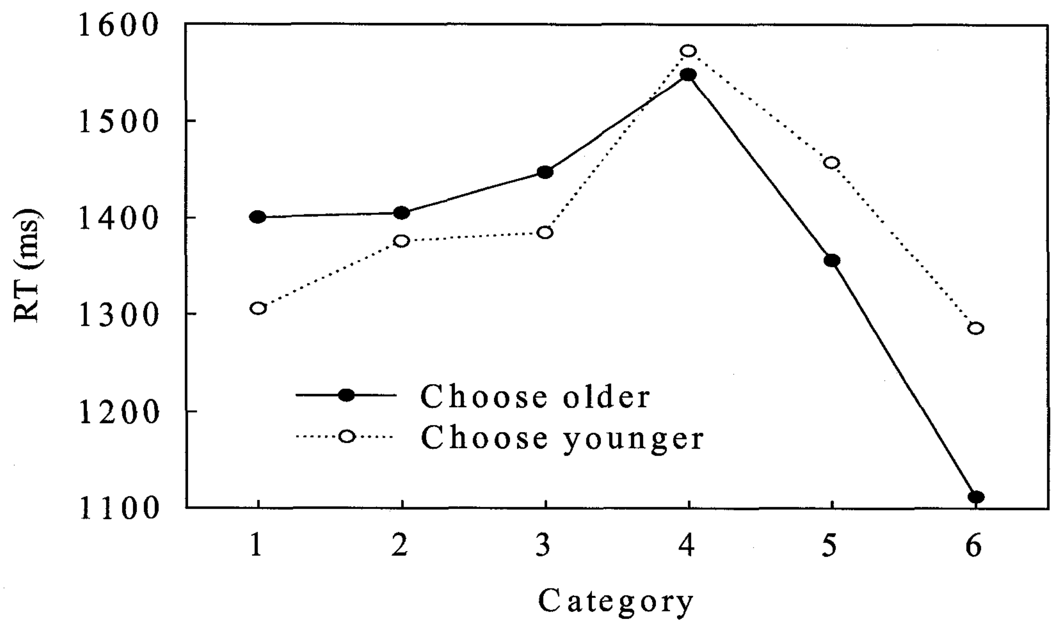

Figure 3. Mean RTs (ms) for Instructions across the Age comparison categories

MARC

There was a possibility that there would be a difference in response times given the markedness of the two words "older" and "younger" with older, the unmarked word, having an RT advantage. A t-test of the mean RTs for each of the instructions for the twenty-five participants showed that response times for the word "younger", with a mean RT of 1397.6, was not significantly different from the response times for the word "older", with a mean RT of 1377.0, $t(24) = -1.384$, $p = .179$. The MARC effect indirectly predicts that the number of times the mean RT is faster should be higher for "older" than for "younger". However the 16 faster mean RTs for older and 9 faster mean RTs for younger, based on the 25 participants, were not significantly different, X^2 (1) = 1.96, $p > .05$.

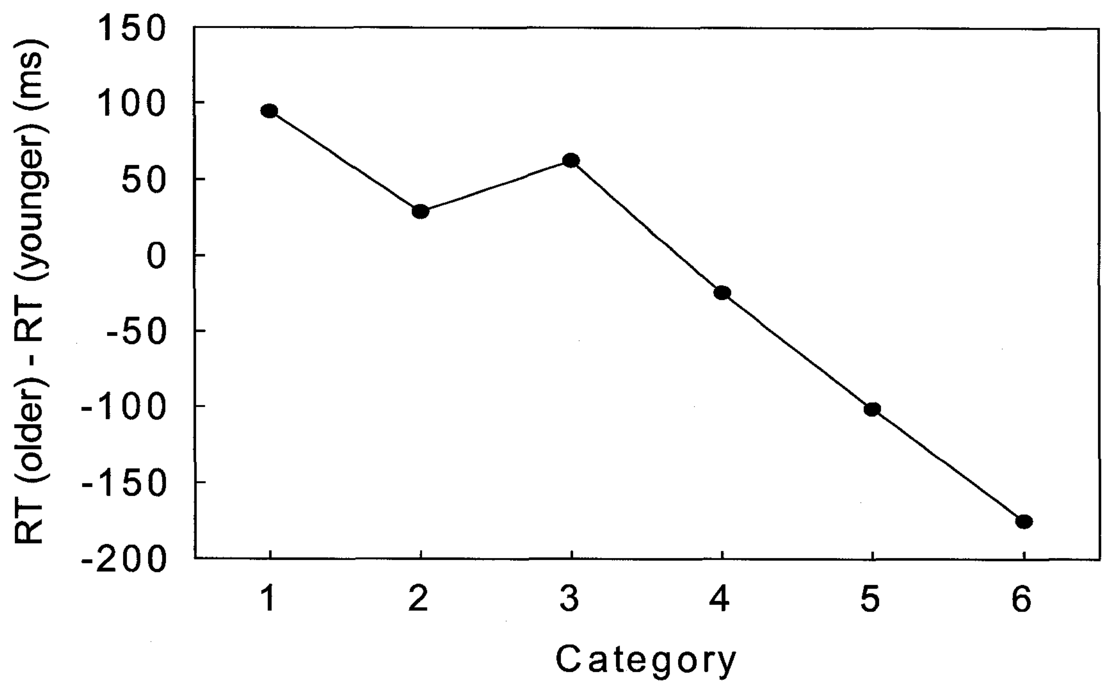

Figure 4. The Semantic Congruity Effect Index determined by the difference between the mean RTs for each instruction for each Age comparison category.

SNARC

The interaction of Hand by Category, as reported in the Interaction section, was found to be significant. Whereas there was a main effect of Hand, with right hand faster than left hand overall, the pattern changed when Hand RTs were separated by Category. Left hand RTs were slower than right hand RTs for Categories 1, 2, 3, 5, and 6, but not for Category 4 (Figure 5). The difference in RTs (dRT) between the two hands clearly showed that the right hand was slower than the left, resulting in the only positive value, only for Category 4 (Figure 6). Hand by Category is the equivalent of side of response by magnitude. This is where we should see a SNARC effect if there is one. As is evident in Figure 6, although the linear component is present $F(1, 24) = 8.68$, $MSe = 107693$, $p < .007$, the overall SNARC effect is rather disorderly. The fitted line for the dRT in Figure 6 resulted in a positive slope with an $R^2 = 0.296$, indicative of a reversed SNARC effect. This relationship may have come about because of an underlying instruction-dependent effect (Petrusic & Shaki, 2007).

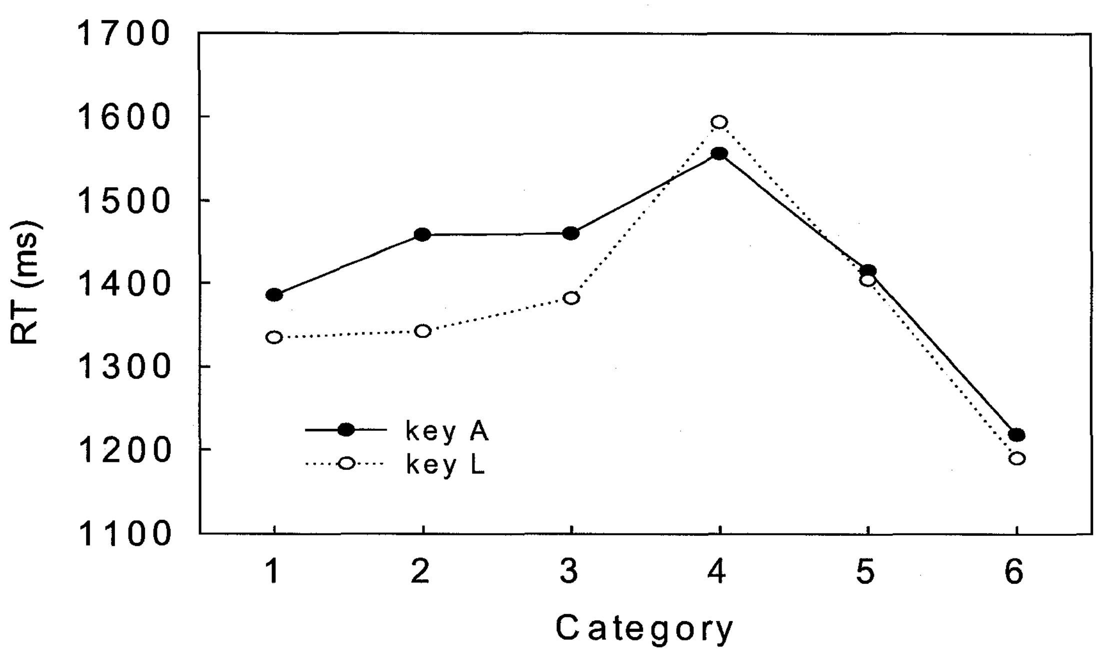

Figure 5. Category by Hand. Key A is on the left hand of the keyboard, and key L is on the right hand of the keyboard.

Petrusic & Shaki (2007) noted that the results for Hand by Category included the combined, and averaged, RTs for the instructions. In a set of experiments using relative sizes of animals, comparing ant - bee for the instructional probe "Smaller", and cow - elephant for "Larger", a SNARC effect was found for each instruction, in the direction of the instruction. This experiment was reproduced in Israel with Arabic and Israeli participants. The same results were found, though reversed due to the reversed direction of reading. Curiously, the absolute values of the slopes were the same for the two regression lines within each language. The result was called an instruction-dependent SNARC, to differentiate it from the SNARC effect derived from Hand by Category. Thus, each instruction might result in dRTs in the opposite direction. The averaging of the two instructions would then be cancelling each other out.

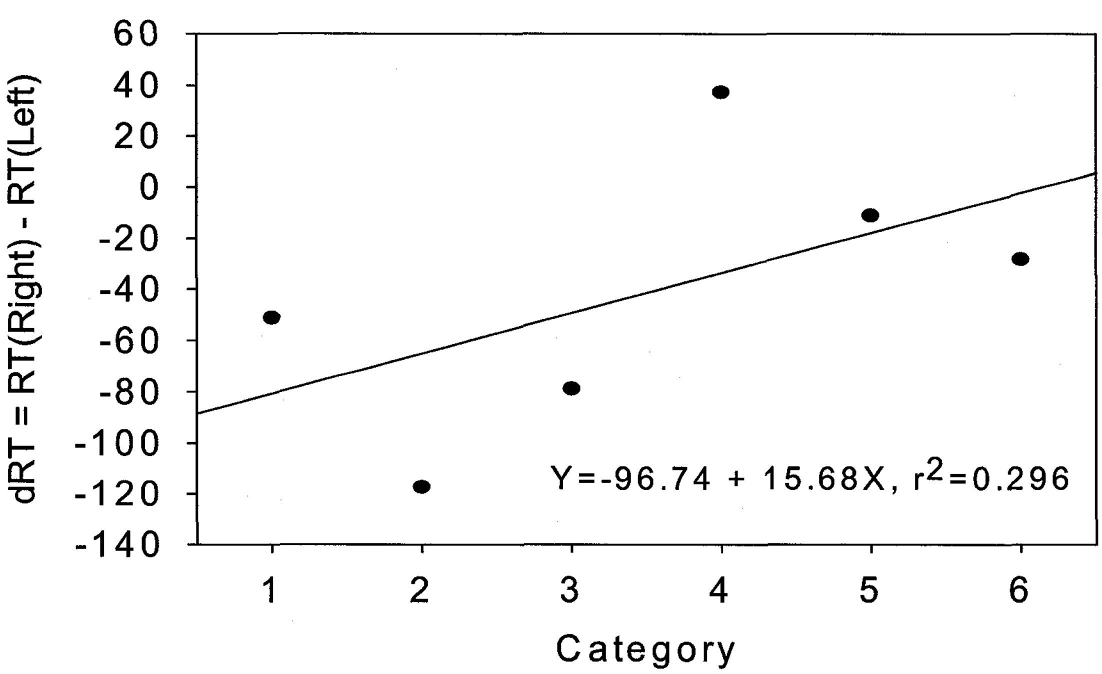

Figure 6. Category by Hand Index. dRT of left hand RT taken away from right hand RT for each Category, showing line of best fit

Within this analysis the Hand by Category interaction was separated by Instruction to check for the instruction-dependent SNARC effect found by (Petrusic

& Shaki, 2007). Taking the mean RT with the left hand from the mean RT of the right hand separately for each instruction at each category revealed an instruction-dependent reversed SNARC effect for the instruction "Younger" (Figure 7). Under the instruction "Younger", the right hand was faster than the left across the three relatively young categories, whereas the left hand was faster than the right across the three relatively old categories. Under the instruction "Older", there was no relationship; five of the six differences in RT were positive. The line of best fit for the instruction "Older" was a negligible R^2 of .059. Under the instruction to choose the younger of the two faces, the line of best fit was an R^2 of .69. A regression analysis was then done to determine if the pattern seen in Figure 7 was significant.

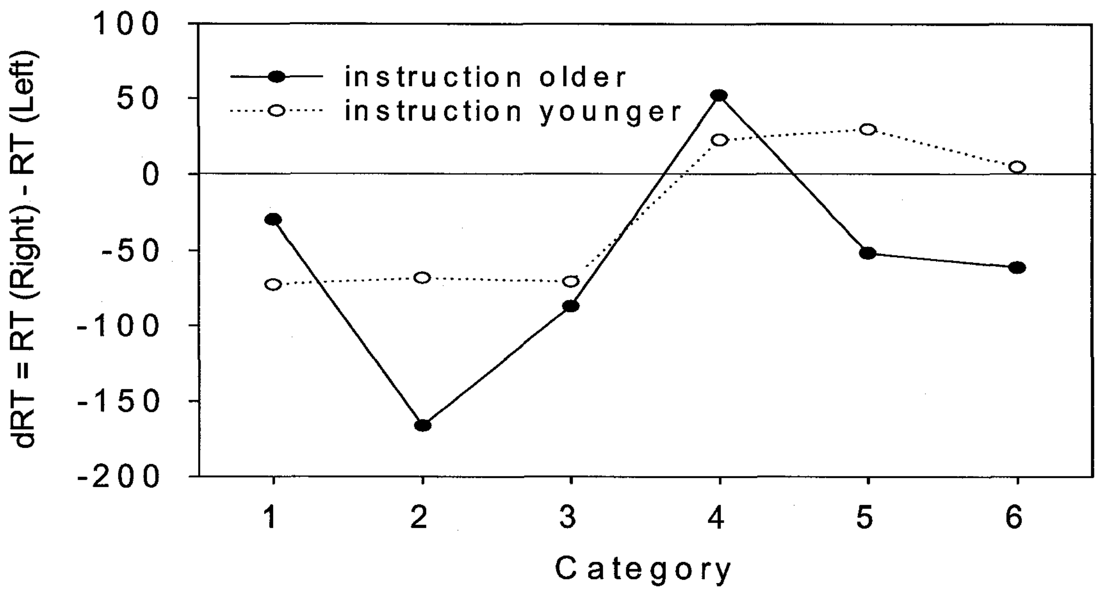

Figure 7. Instruction dependent SNARC. Age comparison category by difference in RT for each hand (dRT) separated out by instruction.

Individual Participant Analysis

A regression analysis of differences of RT (dRT= RT (right hand) – RT (left hand)) was conducted separately for each subject by each instruction, to determine the standardized beta coefficients (Lorch & Meyers, 1990; Shaki & Petrusic, 2005). These sets of coefficients, for the two instructions, were then analyzed using a t-test to determine if they were significantly different from zero. For the "Younger" instruction, the mean beta weight (M=. 262, SD = .392) was significantly different from zero, $t(24) = 3.343$, $p = .003$, 2-tailed. For the "Older" instruction, the mean beta weight (M= 113, SD = .482) was not significantly different from zero, $t(24) = 1.169$, $p > .254$, 2-tailed. Thus the overall linear component of the hand by category interaction arises primarily with the instruction "Younger".

As in the analysis of Shaki and Petrusic (2007) attention was paid to the number of participants whose beta weights or slopes were in agreement. The purpose of this second investigation was to protect against the possibility that the results were affected by a few extreme values skewing the results. The "Older" instruction resulted in 10 positive and 15 negative slopes, demonstrating randomness, $X^2(1) = 1$, $p > .05$. The "Younger" instruction resulted in 19 of 25 participants with negative slopes, supporting the finding of significance, $X^2(1) = 6.76$, $p = 01$.

Gender-presentation analysis

There were four Gender-presentation combinations: male-male, male-female, female-male, and female-female. An analysis of Gender-presentation found no significant main effect, $F(3,24) = .392$, $MSe = 9155$, $p = .697$. The Gender-presentation by Category interaction, though, was significant. As shown in Figure 8 the male-male presentation response times were slower in Categories 1, 2 and 6, but faster in Categories 3, 4, and 5, than the other three gender-presentation types, male-female, female-male, and female-female, $F(15,24) = 2.377$, $MSe = 94306$, $p = .024$.

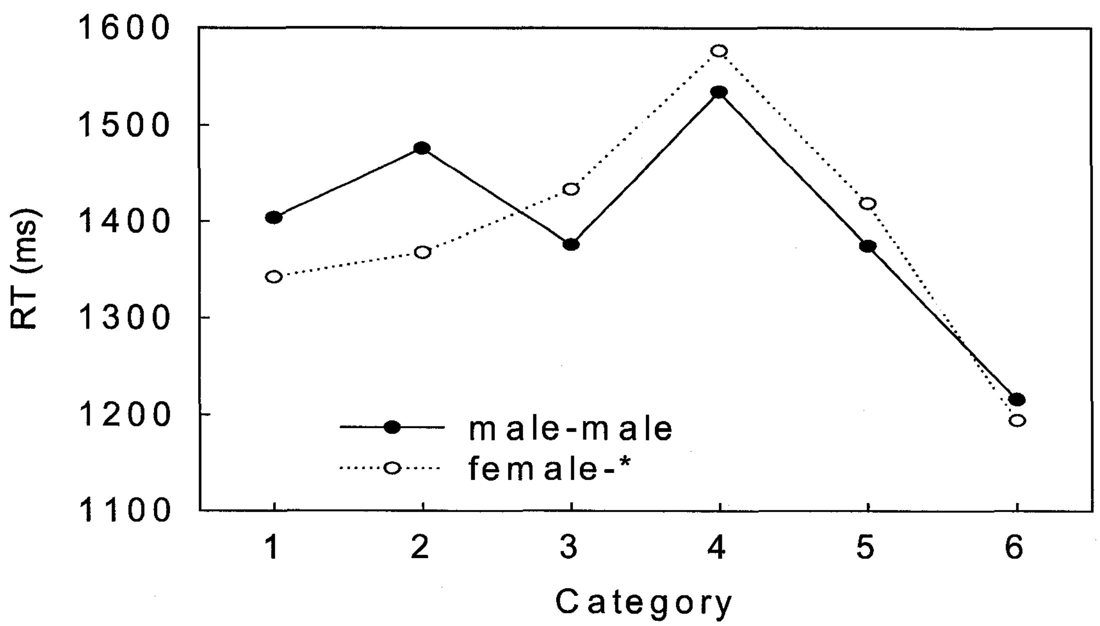

Figure 8. Mean RT for Gender presentation order (solid line is male-male presentation, dotted is at least one female in the presented pair) by age comparison category.

Experiment 3

A SNARC effect was not found in the age comparison task, though there was a partial instruction-dependent SNARC effect for the instruction probe “Younger”. Could there be a SNARC effect when the instructions were made irrelevant? Gevers, Reynvoet, and Fias (2003) ran experiments based on ordinality rather than magnitude, and found a SNARC effect for both relevant and irrelevant instructions. The next experiment uses a task irrelevant instructional probe to check for a SNARC effect that would arise from the implicit age of a face. SNARC could be elicited via magnitude, the age of the face, or its ordinality on a continuum from baby to elder.

Method

Participants

Twenty-seven Carleton University students, nineteen females and eight males, took part in the experiment in exchange for course credit. Their ages ranged from 18 to 38 years with a mean of 20.5 years.

Apparatus

The same apparatus was used as in experiment 2 with one addition. A card was taped below the monitor, indicating the side assigned to True and False. This card could be reversed, so as to reverse the assignation of True and False.

Stimuli and Design

Twenty-eight faces were used, the same faces as used to construct the comparison pairs in Experiment 2, two male and two female faces in each of seven age categories: Baby, Toddler, Youth, Adolescent, Young Adult, Middle Aged, and Elder. Two labels were created, Male and Female, to be used as instructions (Appendix IV). A placard was taped below the screen with either True to the right and False to the left, or False to the right and True to the left. The assignment of True and False to the keys A and L were counterbalanced between blocks. True (left) and False (right) was defined as A. False (left) and True (right) was defined as B. With odd numbered participants, the pattern of the eight blocks was ABABABAB. The pattern for the even numbered participants was inverted, BABABABA. There were 28 single faces, two instructions, and eight blocks, resulting in 448 presentations.

Procedure

The participants sat approximately 80 cm. from the monitor. The instruction, either Male or Female, appeared on the screen for 750ms The face then appeared below the instruction, and the instruction remained on the screen. The participant was instructed to determine whether the instruction and the face matched. If yes, they were to press the key assigned to True. If not, the participant was to press the key assigned to False (Appendix V). The response ended the trial and the next instruction appeared on the screen. Each time the participant came to the end of a block, the participant had a short break while the placard was replaced with the reversed order of True – False. After two practice trials, the participants were instructed to be as quick and as accurate as possible, and the experiment began. The experiment took approximately 20 minutes.

Results and Discussion

As in experiment 2, responses that were either below 200 ms or above three standard deviations above the mean for each participant were not used in the analyses. This resulted in 266 (2%) responses being removed from the data available for analysis. There were 1165 errors across the six Age categories. The Baby category accounted for 647 errors (56%), more than the number of errors in the rest of the categories combined (Figure 9). An RT analysis of the correct responses showed that Baby faces were approximately 300 ms slower than the average of the other six categories (Figure 10). Together, the higher number of errors and the slower RTs indicated the participants had a much harder time identifying the gender of the Baby faces. The Baby category had 987 correct and 647 error responses (Figure 9). In spite of the fact that this category was more difficult to differentiate, the participants were able to determine the gender of the baby at better than guess, $X^2(1) = 70.75, p = .005$. Because of the disproportionate number of errors and the higher than average RT, it was decided that the Baby category was a unique situation, and removed from further analysis in this paper. This removal left 10,196 usable responses of which 518 (5%) were errors.

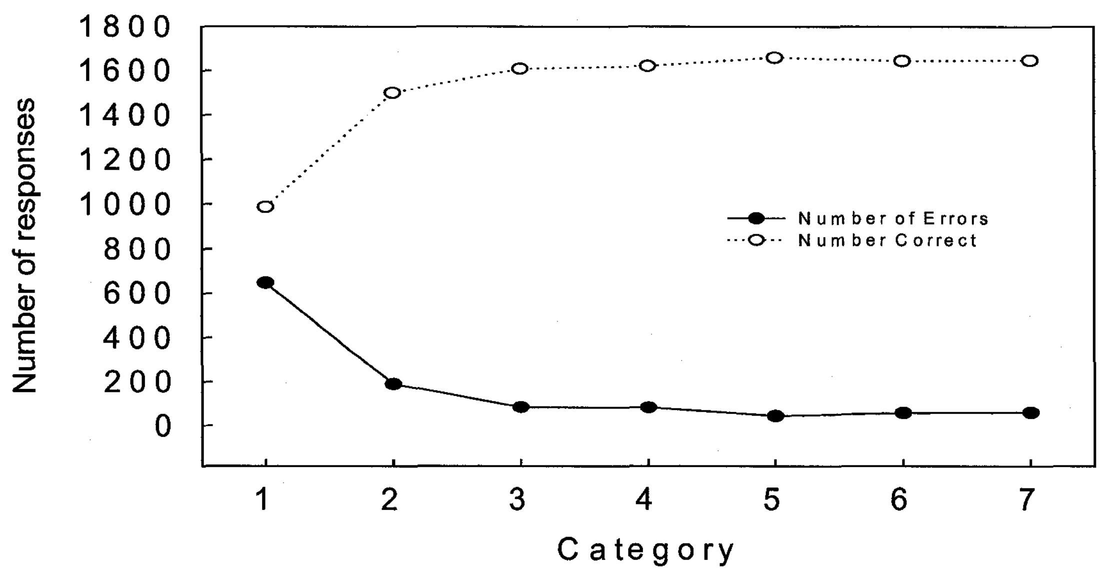

Figure 9. Number of correct and error responses by category. (1 = baby, 2 = toddler, 3 = youth, 4 = adolescent, 5 = young adult, 6 = middle aged, 7 = elder)

As in Experiment 2, the number of male participants was much smaller than the number of female participants. Gender was not used as a between-subjects factor.

All reported repeated measure analyses results used the Huynh-Feldt adjustment. The degrees of freedom reported are those determined by the experimental design.

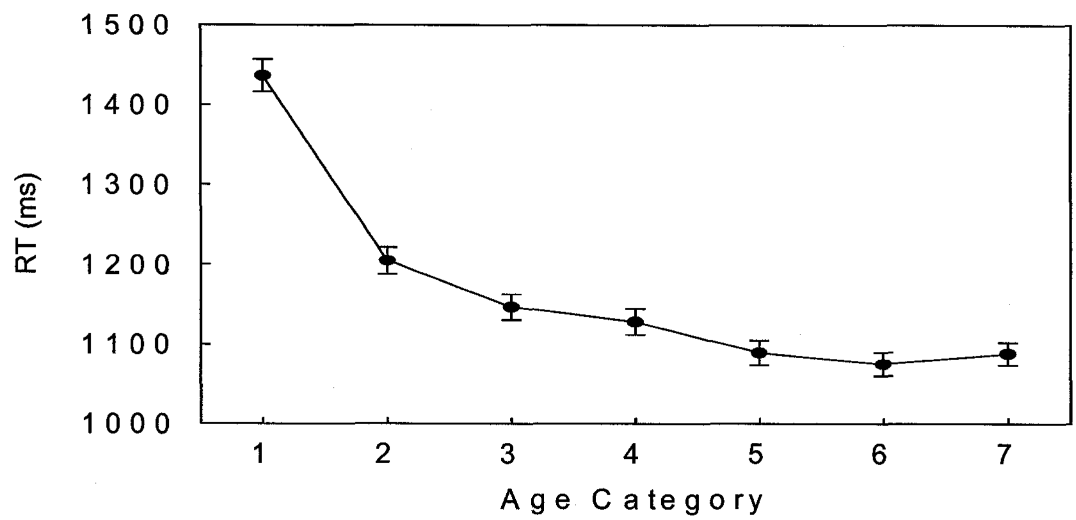

Figure 10. RT for Errors in each Age Category (1 = baby, 2 = toddler, 3 = youth, 4 = adolescent, 5 = young adult, 6 = middle aged, 7 = elder)

Interaction Effects

Four independent variables were analyzed in a general linear model repeated measures ANOVA. The four variables were Age (one of the six age categories, Baby having been removed), Instruction (Male or Female), Face (Male or Female), and Hand (True or False). The four-way interaction, Age by Instruction by Face by Hand was not significant, $F(5, 26) = .377$, $MSe = 29951$, $p = .781$. There were no significant three-way interactions. The only two-way interaction that was significant was Instruction by Face, $F(1,26) = 76.424$, $MSe = 4286400$, $p < .001$.

Main Effects

Age Category was found to be a significant factor, $F(5,26) = 7.23$, $MSe = 364869$, $p < .001$. Participants took longer to respond to Toddler, Youth and Adolescent categories than they did to respond to Young Adult, Middle Aged, and Elder. A main effect of Hand (or side of response) was also found to be significant, $F(1,26) = 10.75$, $MSe = 443400$, $p = .003$. Similar to experiment 2 the left hand was slower than the right hand by 37 ms, as might be expected with a majority of right-handed participants. The handedness of participants was not recorded.

Congruency of face and instruction probe

As already noted an interaction of Instruction by Face was found to be significant. The mean RTs for the two instructions Male and Female for the Male faces were not significantly different as the error bars overlap. However, female faces were responded to more quickly if instruction and face were congruent, female face with female instruction, and more slowly when incongruent, female face with male instruction (Figure 11).

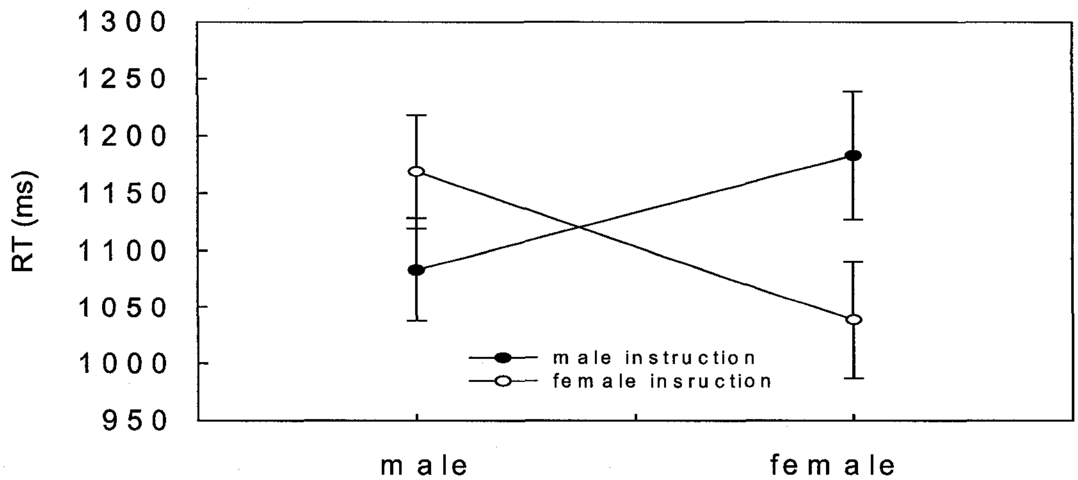

Figure 11. Face by Instruction interaction. Bars represent standard error.

SNARC

SNARC is a side of response by magnitude effect. In this experiment the side of response is represented by Hand and magnitude by Age Category. The graph of the Hand by Age Category interaction (Figure 12) showed a reverse SNARC effect, R^2 = .53. However the ANOVA analyses did not find it to be significant $F(5,26) = .502$, $MSe = 34916$, $p = .672$. As well, each of the orthogonal trend components was non-significant (each $F < 1$). Thus these analyses provide no statistical support for the apparent reverse SNARC effect suggested in Figure 12. Investigating the three-way interaction Age by Instruction by Hand, there was a significant cubic component $F(1, 26) = 4.731$, $MSe = 283175$, $p = .039$. However there was no significant linear component ($F < 1$), and SNARC is recognized by its linearity.

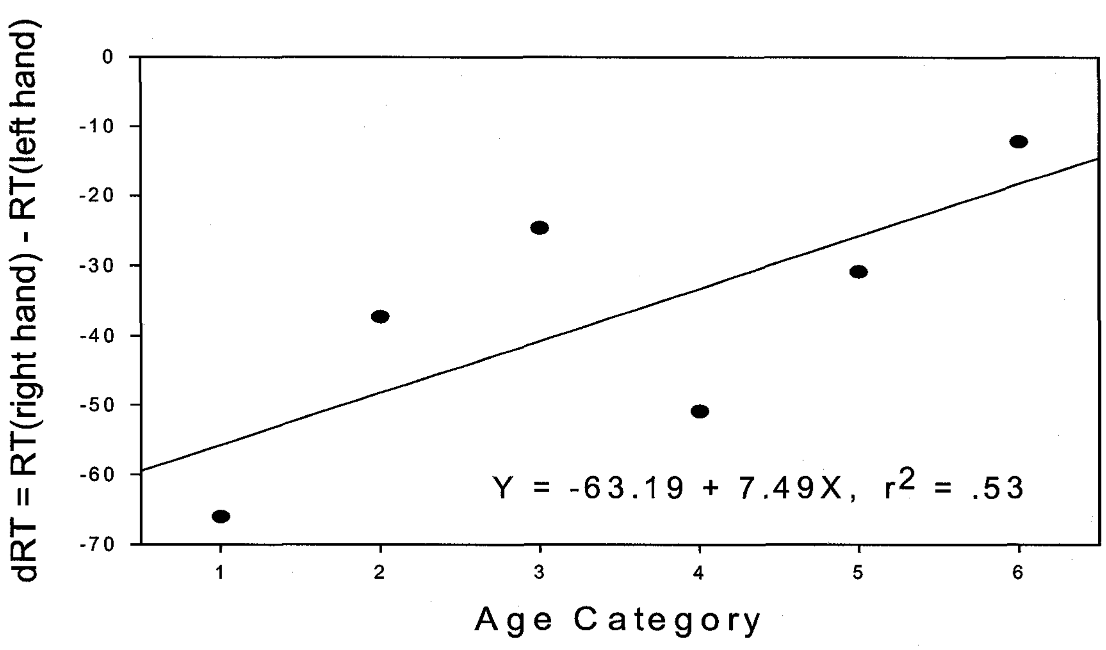

Figure 12. Hand by Category for Experiment 3 with line of best fit.

Block and error analysis

A very clear learning curve was seen over the eight blocks (Figure 13). RTs dropped from an average of 1384 ms in Block 1 to 986 ms in Block 8, $t(7) = -3.742$, $p = .007$, 2 tailed. The RTs for errors in each block also became faster, dropping from 1839 in Block 1 to 1209 in Block 8, $t(7) = 14.391$, $p < .001$, 2 tailed. The RTs for both correct and error responses paralleled each other, dropping systematically (Figure 15).

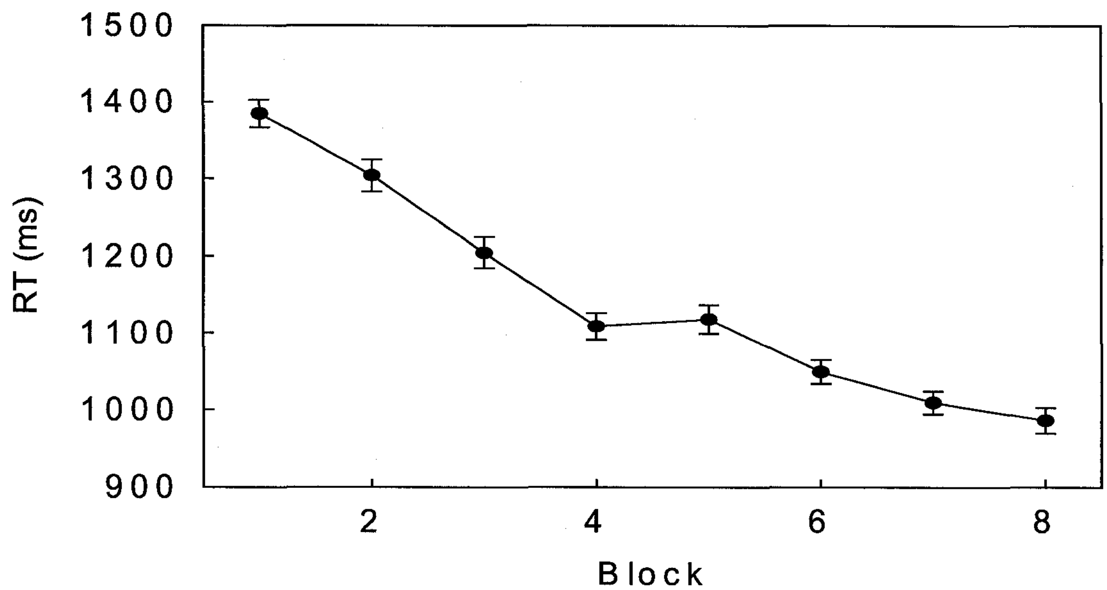

Figure 13. Age Category by Hand separated by True and False responses. dRT represents the RT difference between True on the right side, and True on the left side.

The number of error and correct responses was quite flat across the blocks (Figure 14). The number of errors across the blocks ranged from a low of 137 in Block 8 to a high of 164 errors in Block 5, $t(7) = .009$, $p > .993$, 2 tailed. Together, the flatness of number of errors and the parallel RT decrease for correct and error (Figure 15) demonstrated that there was no Speed – Accuracy Tradeoff.

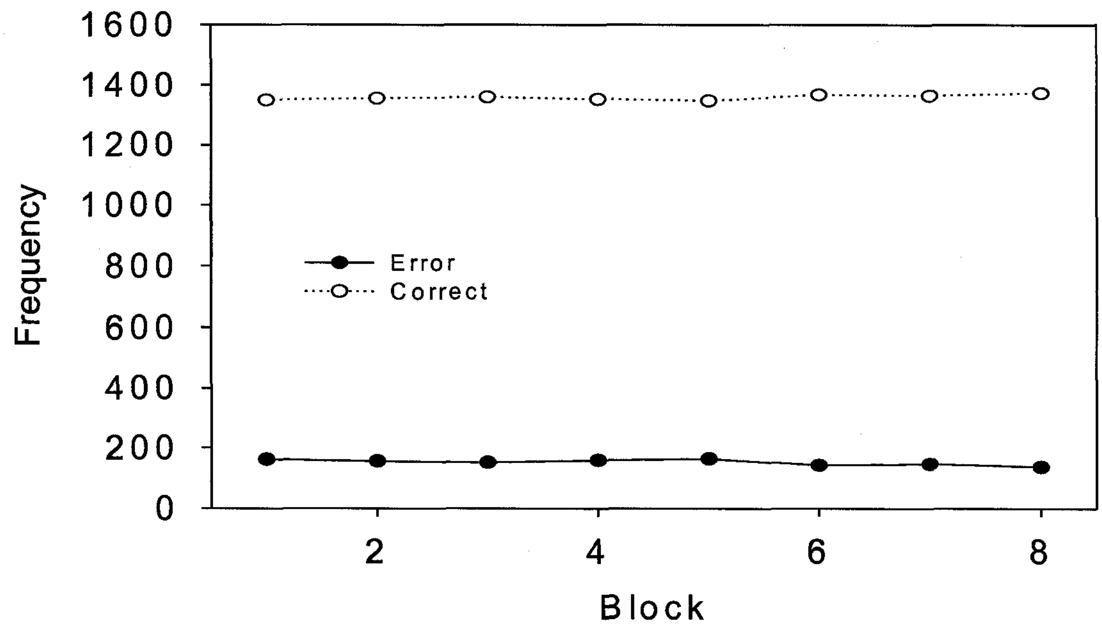

Figure 14. Error and Correct response frequencies across the Blocks

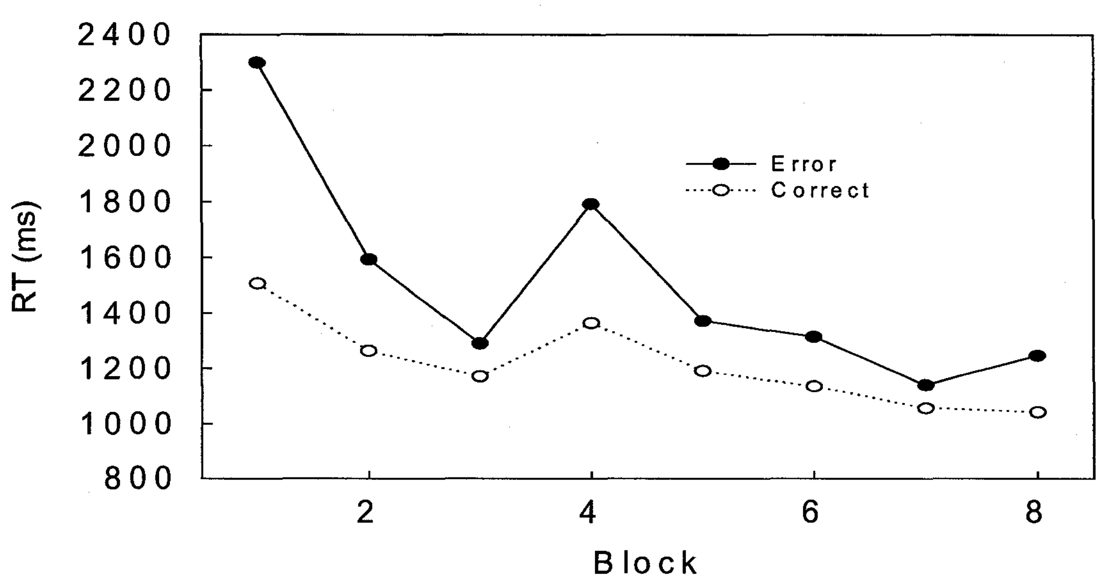

Figure 15. Mean Error and Correct RTs for each Block

General Discussion

Semantic Congruity Effect and Congruity Matching

Experiment 2 found a full crossover effect for the two instructions ("Younger" and "Older") in a comparative judgment task. Experiment 3 found a partial crossover effect, a variation called a *funnel effect*. These experiments supported the many previous findings that congruity of instruction and stimulus leads to faster RTs than incongruent instruction and stimulus (Audley & Wallis, 1964; Petrusic & Baranski, 1989; Wallis & Audley, 1964).

SNARC effect not found

Is the SNARC effect a result of magnitude rather than ordinality as originally reported by Dehaene et al. (1993)? Gevers et al. (2003) found that the SNARC effect could be found via the ordinal information inherent in the months of the year, and the alphabet, both well-learned ordinal sequences. This then asked the question: is the SNARC effect caused by magnitude, or really driven by order? The data to date are not decisive if the effect caused solely by magnitude, but the cause is at least ordinal.

Thus the major purpose of the experiments in the present research was to discover whether faces had either a magnitude or an ordinal component to them that would be automatically activated when presented with faces of differing ages. Neither experiment 2 nor experiment 3 found a side of response by magnitude, or SNARC, effect. In experiment 2, using a forced-choice "choose Younger (Older)" task, the hypothesis was that we maintain an order of people's ages ranging from baby to elder, and more, that we estimate people's ages when making judgments. Experiment 2 provided no supporting evidence for this hypothesis. Experiment 3 provided conclusive evidence that a person's face does not automatically activate numerical age.

Another layer of analysis separated "Hand by Age Category" by the two instructions, "Younger" and "Older", paralleling the Petrusic and Shaki (2007) research, which had found an instruction-dependent SNARC effect in a size comparison task. In other words, they had found that when the instruction defined how the participant was to think about the stimuli, an ordering of relative sizes did occur. The direction of the SNARC effect was dependent on the instruction, and the language. The size of animal ordering seemed to be anchored by the instruction, such that in the regression analyses the slopes of the two best fitting lines were inverses of each other. That is to say, for the instruction Smaller, the participants seemed to view the six animals from smallest to largest, while with the instruction Larger, the participants seemed to line the animals from largest to smallest, resulting in a cross-over effect for the two instruction-dependent SNARC effects. Of equal interest was the result that in Hebrew the instruction-dependent SNARC effect was reversed, following the pattern of results that show that the direction of SNARC follows the direction of reading and writing.

In the present experiment a reversed SNARC effect was found for one instruction, "Younger", but not for the other, "Older". The additional individual participant regression analysis showed that the participants' mean slopes were positive for the "Younger" instruction. This partial instruction-dependent reverse SNARC effect is surprising. If age is ordinal, then it is reasonable that we order faces from youngest to oldest. Yet under the instruction "Younger", the right hand was faster than the left for the younger categories, and the left hand was faster than the right for the older categories. This is the reverse of what was expected, and suggests that under the instruction "Younger" the participants accessed the order from oldest to youngest. Under the instruction Older, the left hand was slower than the right hand for five of the six categories, and there was no SNARC effect.

Why was there an effect for the instruction "Younger", but not the instruction "Older"? Could it have been that the participants in experiment 1 were predominantly young adults? The median age of participants was 19 years and the changeover in the results was at this age, going from a negative dRT for Category 3 (youth – adolescent), to a positive dRT for Category 4 (adolescent – young adult). To answer the question, whether there would be a different direction to the instruction-dependent SNARC effect due to age of participant, this experiment would need to be repeated with groups of participants of differing ages, including youth and elders.

Another result to note in experiment 2 was the dRTs themselves. The three dRTs for Categories 1 through 3 were each negative and the same. The three dRTs for Categories 4 through 6 were positive, and were again the same. This indicates that the separation of ages is categorical. Following the previous argument about the median age of the participants, it appears that the instructions might have separated the stimuli into two larger categories, older than the participants, and younger than the participants. There might be some form of anchoring occurring wherein the participants are making comparative judgments not only between the pairs of faces, but also in reference to their own age.

Experiment 3 did not find SNARC effects. Although the line of best fit for "Hand by Category" for True and False, had a high R^2, the ANOVA analysis was not significant. In this True or False task there were no age related cues in the instructions. The ages of the faces, whether toddler or elder, were irrelevant to the task. It appears that participants used features rather than magnitude or ordinal information to complete the age judgment task. This would be in line with the Fias, Lauwereyns, and Lammertyn (2001) finding that feature dependent judgments did not result in a SNARC effect.

In both experiment 2 and 3, the SNARC effect was not found in its pure form, that is, under the Hand by Age Category analysis. These findings suggest that we judge whether one face is older than another by means of the features rather than by estimating each face's age or by accessing some internal ordinal representation of age.

The Dehaene (1993) experiments added evidence for an internal representation of the world, at least for the analog representation of a number line. But could we have two systems at work? Maybe for concepts such as numbers we need to create mental representations. However, it was noted that illiterates who were number aware did not exhibit a SNARC effect (Zebian, 2005). The illiterate participants did not appear to have developed an internal representation of the number line. Could it be that illiterates store numbers in memory?

Referring back to the introduction of this thesis and the example of the mosquito and the incoming baseball, there is no need to access an internal representation of the world around us. It would be more efficient to act directly upon the incoming stimuli themselves. However, concepts such as numbers are not real in of themselves but rather representations. For example the concept "one" simply explains the amount, but nothing about the object it is describing. A ball is a real world object that a person can physically manipulate. The word "one" is a concept that must be mentally manipulated. This manipulation would be facilitated by an internal representation, a mental model that would more easily facilitate a physical response.

Future experiments

Two faults in the experiments, conducted for this thesis, were the lack of participant gender balance and their unknown handedness. This should be addressed in future experiments.

There have been experiments with deaf participants using visual stimuli, and recently an experiment with blind participants using aural stimuli (Castronovo & Seron, 2007). However, testing whether the direction of the SNARC effect is dependent on the direction of reading brail has not yet been tested for the blind.

It was also noted in this paper that participants might divide ages of faces into two categories, those older than themselves, and those younger. If this is indeed the case then it is expected that participants of differing ages would have differing results dependent on their age. As such further experiments with groups of participants from youth, adolescent, middle aged, and elder groups would elucidate this question.

The SNARC effect has been used to test models, and has provided evidence that people do maintain a mental model of the world that is used when making judgments. When the effect is absent, is this evidence that we are not using an internal representation but rather making decisions based solely of the physical world outside our minds? And if these two strategies of interacting with the world are both true, then the philosophies of Aristotle and Plato can co-exist.

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Appendix I. Examples of Stage 1 Stimuli

Single image stimuli

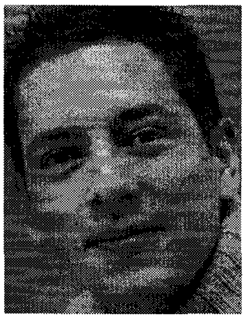
Baby

Toddler

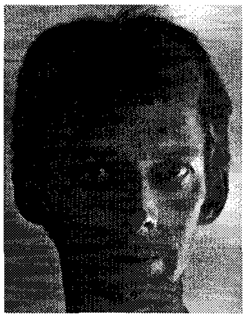
Youth

Adolescent

Young Adult



Middle Aged



Elder

Appendix II. Instructions for experiment 2

Explanatory instructions verbally presented:

"I will run through what will happen. First one of two instructions will appear on the screen, either Younger or Older, younger meaning choose younger, older meaning choose older. Next two photographs will appear, one face will be younger, one older [or one face will be older, one younger]. Choose the face corresponding to the instruction."

Demonstration

"Press any key. Note the two keys on either side of the keyboard. Press the key that is on the same side as your choice."

Instruction appears, then instruction with two faces

"go ahead.."

Second example appears.

End of demonstration

"Do you have any questions? By the way how old are you? (Record age) Please be as accurate and as quick as you can. There are a lot of faces, and the experiment will take 30 – 35 minutes. I will leave the room, and close the door so you can have your privacy. If there are any problems come and see me. Press any key to begin, once I have left the room. Thank-you for your participation."

Leave room, and close door

Appendix III. Examples of Experiment 2 Stimuli

Baby – Toddler

OLDER

Toddler - Baby

YOUNGER

Toddler – Youth

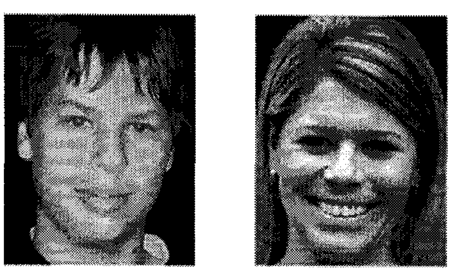
YOUNGER

Youth – Adolescent

OLDER

Adolescent – Young Adult

OLDER

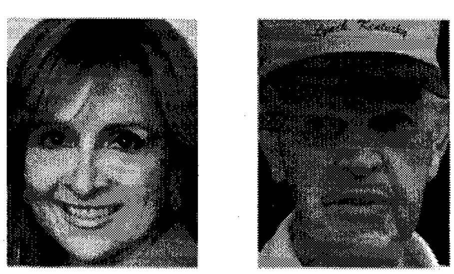


Middle Aged - Young Adult

OLDER

Middle Aged - Elder

OLDER



Appendix IV. Instructions for Experiment 3

Explanatory instructions verbally presented:

I will explain what will happen. First an instruction will appear on the screen. It will say Male, or it will say Female. Then a photograph of a face will appear below the instruction. If the instruction and the photograph match press the button marked "True", otherwise press "False".

Demonstration

For example… (instruction appears on screen, then photograph of a face) …go ahead and make your choice… (after a key is pressed the next instruction followed by the next photograph of a face appears on the screen) … and again.

End of demonstration

Ok any questions? Good. Try to be as quick and as accurate as you can. When you come to the end of this block come and see me. You can begin after I leave. Press the space key.

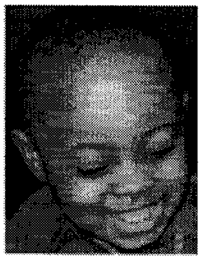
Resetting the order of True and False

Now we will change the order of the keys. This side will be False and this will be True. When I have left, press the number 5 and begin.

Appendix V. Examples of Experiment 3 Stimuli

Toddler
Instruction Incongruent

FEMALE

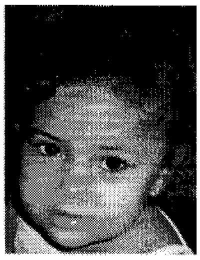


Toddler
Instruction Congruent

MALE

Toddler

FEMALE



Youth

MALE

Middle Aged

FEMALE

Elder

FEMALE