of/de

PIONEERS IN METHYLENE BLUE TESTING SINCE 1974

1900 LEXINGTON ROAD S. BURNSVILLE MN 55337 USA
TEL 612 426 7887 FAX 612 426 7887 Tlx 5108000000

National Library
of Canada

Bibliothèque nationale
du Canada

Canadian Theses Service Service des thèses canadiennes

Ottawa, Canada
K1A 0N4

NOTICE

The quality of this microform is heavily dependent upon the quality of the original thesis submitted for microfilming. Every effort has been made to ensure the highest quality of reproduction possible.

If pages are missing, contact the university which granted the degree.

Some pages may have indistinct print especially if the original pages were typed with a poor typewriter ribbon or if the university sent us an inferior photocopy.

Reproduction in full or in part of this microform is governed by the Canadian Copyright Act, R.S.C. 1970, c. C-30, and subsequent amendments.

AVIS

La qualité de cette microforme dépend grandement de la qualité de la thèse soumise au microfilmage. Nous avons tout fait pour assurer une qualité supérieure de reproduction.

S'il manque des pages, veuillez communiquer avec l'université qui a conféré le grade.

La qualité d'impression de certaines pages peut laisser à désirer, surtout si les pages originales ont été dactylographiées à l'aide d'un ruban usé ou si l'université nous a fait parvenir une photocopie de qualité inférieure.

La reproduction, même partielle, de cette microforme est soumise à la Loi canadienne sur le droit d'auteur, SRC 1970, c. C-30, et ses amendements subséquents.

Semantic Congruity

Semantic Congruity and Age Comparisons:
Towards a Theory of Psychological Age

Kathryn J. Oakley-McKeen

M.A. Thesis

Department of Psychology

Carleton University

Thesis Supervisor: Dr. William M. Petrusic

Running Head: SEMANTIC CONGRUITY AND AGE COMPARISONS

National Library
of Canada

Bibliothèque nationale
du Canada

Canadian Theses Service Service des thèses canadiennes

Ottawa, Canada
K1A 0N4

The author has granted an irrevocable non-exclusive licence allowing the National Library of Canada to reproduce, loan, distribute or sell copies of his/her thesis by any means and in any form or format, making this thesis available to interested persons.

The author retains ownership of the copyright in his/her thesis. Neither the thesis nor substantial extracts from it may be printed or otherwise reproduced without his/her permission.

L'auteur a accordé une licence irrévocable et non exclusive permettant à la Bibliothèque nationale du Canada de reproduire, prêter, distribuer ou vendre des copies de sa thèse de quelque manière et sous quelque forme que ce soit pour mettre des exemplaires de cette thèse à la disposition des personnes intéressées.

L'auteur conserve la propriété du droit d'auteur qui protège sa thèse. Ni la thèse ni des extraits substantiels de celle-ci ne doivent être imprimés ou autrement reproduits sans son autorisation.

ISBN 0-315-75932-1

Canada

*The undersigned recommend to the Faculty of Graduate Studies
and Research acceptance of the thesis*

SEMANTIC CONGRUITY AND AGE COMPARISONS:

TOWARDS A THEORY OF PSYCHOLOGICAL AGE

Submitted by Kathryn J. Oakley-McKeen

*in partial fulfillment of the requirements for
the degree of Master of Arts*

A handwritten signature in dark ink, appearing to read "William McKee", written over a horizontal line.

(Thesis Supervisor)

A handwritten signature in dark ink, appearing to read "Bill Dwyer", written over a horizontal line.

Chair, Department of Psychology

Carleton University

March 31, 1992

Abstract

A quantitative index of psychological age was obtained using a psychophysical discrimination methodology. In Experiment 1, subjects categorized 151 photographs of faces into 7 age categories (from infants to 100 years of age). In Experiment 2, subjects compared pairs of faces from adjacent age categories selecting the 'younger' on half of the trials and the 'older' on the other half. Comparative judgement response times (CJRT) increased with age. In addition, semantic congruity effects (SCE) were evident for each of three age groups. These two findings taken together suggest that the rate of evidence accrual varies as a function of age. The Point of Intersection (POI; the point on the age continuum where the SCE is zero) increased monotonically with the age of the group. Gender differences also occurred in the locus of the POI; that is, females had a younger POI than males, regardless of age. Subjects also provided binary categorizations ("Young" vs "Old") of the stimuli used in the comparison task, and the Category Boundary (the PSE on the psychometric function) was invariant with age. This failure to find variation in the category boundary age taken together with systematic increases in the SCE based POI with age and gender, is problematic for both the Semantic Coding and the Reference Point theories of the SCE. At least both classes of theories must make auxiliary assumptions about the growth of subjective age with chronological age.

Acknowledgements

I wish to sincerely thank my advisor, Dr. William M. Petrusic, for his support and encouragement throughout this thesis, through a Natural Sciences Research Grant No. APA 0238. I am especially appreciative of Dr. Petrusic's flexibility in providing me the opportunity and the freedom to combine two areas of research. I would also like to thank Joe Baranski and Louise Plouffe for their helpful suggestions; the committee members, Dr. Charles Gordon, Dr. Chris Herdman, and Dr. William Jones for their careful consideration of my thesis, with a special thanks to Dr. Tom Tombaugh for his generosity of spirit and incalculable assistance throughout this thesis; and Rick Mallett and Dan Cote for computer programming expertise.

Many thanks are also extended to my husband, John, for his patience, understanding, and unfailing support.

SEMANTIC CONGRUITY AND AGE COMPARISONS: TOWARDS A THEORY OF
PSYCHOLOGICAL AGE

A growing concern in the literature on the psychology of aging is the voluminous amount of research that exists without sufficient theory to drive it (Birren & Bengtson, 1988; Salthouse, 1985). One reason cited for lack of theory construction is the large number of contradictory findings (Schonfield, 1989). Schonfield (1989) stated that conflicting data may be the result of different methodologies, the result of "looseness of language" amongst researchers, and a high probability that aging is a multidimensional process.

An additional reason for contradictory results in research on aging may stem from the use of chronological age as a dependent (DV) or independent variable (IV). For example, a commonly used statistical method for controlling for correlation between DVs (MANCOVA) is inappropriate because one of the DVs (age) is also correlated with the IV (Tabachnick & Fidell, 1989). If the researcher is interested in studying the effects of aging directly, the alternative is to use an Attribute Treatment (ATI) design, (Pedhazur, 1982; Tabachnick & Fidell, 1989) which utilizes age as a IV of interest. Unfortunately, the ATI design has low reliability (Pedhazur, 1982), and does not predict or explain why two individuals of the same chronological age may perform differently on a task.

Several attempts, however, to produce an alternative

measure of chronological age in order to accommodate individual differences in functionality, cognitive processes, etc. have to date proved limited, and thus constrains the development of theories of aging. This thesis presents preliminary research toward the formulation of an alternative (non-chronological) index of aging for use in psychological research by investigating the influence of one's own age on the perception of age using a psychophysical discrimination task. To explore this objective, first a brief discussion of relevant aspects of aging are provided (i.e., terminology, components, linearity/non-linearity, uni- and multidimensionality, and the use of direct/indirect measures), with emphasis on psychological age. Next, a discussion of semantic congruity and the relevance of the point of intersection (POI) of the semantic congruity effect (SCE) in investigating the aging process is outlined. This is done in order to examine the effects of age on the comparative judgement process (i.e., SCE) and to determine whether the SCE based POI would serve as a quantitative index of psychological age. Thirdly, two existing quantitative models designed to explain the underlying structure of the comparative process of choice discriminations and binary categorizations (Semantic Coding and Reference Point theories) are compared in order to determine whether discriminations and categorizations of age are decisional or a post-decisional process. It was thought that this comparison might provide insightful information regarding the

locus of process(es) associated with perception of the normal aging process. Finally, age and gender differences are examined, since the literature indicated differences exist (Posner, 1977; Sternberg, 1975).

THE AGING PROCESS

One of the difficulties in establishing a non-chronological measure of age is due to confusion between investigating the 'aging process' versus the 'process of aging'. For example, the 'aging process' refers to normal aging, whereas the 'process of aging' refers to disease processes which interact with normal aging (Fozard, Metter & Brant, 1990).

Further confusion arises between the terms 'age differences' and 'aging process'. To elaborate, 'age differences' in research refers specifically to differences in performance based on chronological age (Schaie, 1972), which cannot explain individual differences between individuals of the same chronological age. The 'aging process', on the other hand, is assumed to be an underlying universal process that occurs from birth to death, within the context of the entire human life span, and takes into consideration variability between individuals of the same chronological age. This thesis focused on the normal 'aging process'.

Biologists measure physiological changes at the cellular level in an effort to identify the locus of the aging or disease process. While considerable progress has been made in this area,

a singular physiological focus is considered insufficient on its own. For example, individuals born at the same moment live to different ages, and different biological functions do not necessarily decline at the same rate. This implicates the impact that psychological and social factors have on contributing to biological changes. Thus, several constructs have been postulated to account for the different processes associated with normal aging. These include biological, social, and psychological age.

Biological Age refers to physiological functioning over time (Turner & Helms, 1982) and "is an estimate of the individual's present position with respect to his or her potential life span" (Schroots & Birren, 1990, p. 47).

Social Age refers to one's social role behaviour as it relates to a given society (Schroots & Birren, 1990). In other words, individuals change their behaviour according to the age-graded system of a society, such that behaviour that is considered acceptable for a 20-year old would not be considered appropriate for a 60-year old. Different measures of social age include 'Do Age' and 'Identity Age', where Do Age reflects those activities the individual is actually engaged in, and 'Identity Age' identifies the age group which the individual associates him/herself with.

Psychological Age refers to the ability to adapt to an increasingly complex environment, and is dependent upon

"age-related adaptive capacities of the individual, such as perception, learning and memory" (Schroots & Birren, 1990, p. 50).

While the above three indices of age have been postulated to replace chronological age as predicted or explanatory variables in studies of aging, Schroots and Birren (1990) pointed out that to date all three non-chronological age indices are measured in units of chronological age. Since chronological age is usually highly correlated with both DVs and IVs, it follows that these three alternate indices are also highly correlated with dependent and independent variables and, therefore, subject to the same limitations as chronological age. This means that the above indices will have to be scaled using a non-chronological scale (i.e. a non-linear and/or multidimensional scale), if they are to be useful in research on the aging process.

Researchers and clinicians have known for some time that underlying psychological processes do not change at the same rate. That is, many cognitive processes exhibit some non-linear decline, others do not change, and some even exhibit a small increase. Thus, large differences within an individual cannot be explained using a linear index of age based on calendar time.

It has also become generally accepted that aging is a multidimensional process (Schonfield, 1989), resulting from the interaction of biological, social, and psychological aging.

Since chronological age is uni-dimensional, it precludes its usefulness as an appropriate index of aging. Clearly, there are other variables at work, and examining differences between chronological age groups is unlikely to provide information about the complexity of the aging process itself, unless the differences are measured on an alternative non-linear and/or multidimensional age scale, or one that taps all three simultaneously.

Despite the fact that researchers in all fields investigating the aging process generally concur that biological, psychological and social factors interact with one another and contribute differently to the lifespan of the individual, no satisfactory alternative index of age has yet been developed to replace chronological age. When appropriate indices of each of biological, social, and psychological age are developed, they will need to be amalgamated to derive an alternative multidimensional age index, in order to achieve a fuller understanding of the underlying aging processes that vary from one individual to another. This research was restricted to formulating an index of psychological age.

An extensive search of the literature indicated that researchers use direct (subjective) methods to measure different aspects of psychological aging (e.g. Barak, 1987) since no unobtrusive indirect measure of psychological age currently exists. Direct methods, however, rely on self-reporting by the

individual and often produce biased or unreplicable results because they are dependent on the honesty and self-awareness of the individual (Brown, 1983). More recently, however, Tombaugh and Faulkner (1990) pointed out that perhaps "objective and subjective measures are both useful and provide valuable, albeit different, information about the aging process. The former may reflect a physiological decline while the latter may be more related to social and personality variables" (p. 14). While this statement has considerable face validity, the lack of unobtrusive indirect measures make it difficult to validate. The statement also hints at the complexity of the aging process, which contributes to the difficulty of theory development.

The main purpose of this paper is to formulate a quantitative index of psychological age using existing objective psychophysical discrimination and categorization measures, on the assumption that a person's psychological age is reflected in the time (and accuracy) required to perform various tasks. The utility of the development of an indirect, non-linear and/or multidimensional, psychophysical measure of subjective or psychological age (one that would help elucidate a quantitative theory of the aging process) was explored. The psychophysical measures used in this study are indirect (objective) measures (i.e. discrimination and binary categorization) that make no assumptions about the linearity or uni-dimensionality of the underlying psychological scale.

Before an explanation can be given regarding the utilization of the point of intersection (POI) of the semantic congruity effect (SCE) as an index of psychological age, a discussion of the semantic congruity effect and its corresponding POI is first provided. Should the locus of the POI of the SCE increase with increasing age, support for its use as an index of psychological age will be given. Thus, a more detailed description of two quantitative models that make specific predictions about the locus of the SCE based POI will also be given in order to subsequently test the possibility of using either model as a general theory to account for individual differences in the aging process.

SEMANTIC CONGRUITY

Shipley, Coffin, and Hadsell (1945) noted that the time required to select the 'most preferred' of two colour patches was faster for colours rated high on a preference scale than for those rated low on the preference scale. Subsequently, Shipley, Norris, and Roberts (1946) found that if asked to choose the 'least preferred' of two colour patches, subjects were now faster at choosing colours low on the preference scale than those high on the preference scale. These researchers concluded that the time required to make a comparative judgement was possibly a general phenomenon, and not tied to either the experimental methodology or the type of stimuli used. Unfortunately, the connection between the inverse relationship of these two

experiments was not made until much later by Audley and Wallis (1964).

Audley and Wallis (1964) established that the time required to choose between two stimuli on a given dimension varied monotonically as a graded (continuous) function of the interaction between the location of the stimuli along a continuum and the direction of the judgement. For example, the time required to choose the brighter of two bright stimuli was less than the time required to select the darker of two bright stimuli and, conversely, subjects were faster at choosing the darker of two dark stimuli than they were at selecting the brighter of two dark stimuli. They named this interaction the crossover effect (COE) for obvious reasons (see Figure 1). Recent North American literature refers to this effect as the semantic congruity effect (SCE) reflecting the linguistic-semantic nature of the effect (Banks, Clark, & Lucy, 1975). The terms COE and SCE will be used interchangeably in this thesis.

Insert Figure 1 about here

The COE or SCE, however, is rarely perfectly symmetrical. A common variation is the funnel effect (see Figure 2). The funnel effect was first found for brightness discriminations, where the magnitude (difference in time) was "zero at the lowest level of luminance and maximum at the brightest" (Audley &

Wallis, 1964, p. 61). A funnel effect was also obtained in a subsequent experiment using difficult pitch discriminations (Wallis & Audley, 1964). These researchers concurred with Shipley and colleagues that the COE phenomenon (full or funnel) was probably common to all judgements, and not peculiar to brightness discriminations.

Insert Figure 2 about here

The funnel effect was subsequently believed to be a result of lexical markedness (Clark, 1969). Clark explained that response time (RT) would be faster for the unmarked form of the comparative (e.g., heavier, larger, brighter, older) because it requires less storage space in memory. The faster RT would shift the COE towards the continuum end associated with the marked comparative (e.g., lighter, smaller, darker, younger). The comparative is 'unmarked' because it refers to the entire scale, whereas 'marked' refers only to one half of the scale (see Figure 3). For example, if we ask how old someone is, this question applies equally well to young children as it does to 90-year old adults. The position on the scale is, therefore, neutral for the unmarked comparative, and thus requires less storage space in memory, which enables the individual to make a faster response to the question "Older?". On the other hand, if we ask how young someone is, the assumption is that the person must already be

young. Thus, the marked comparative cannot be neutral and, therefore, assumes a locus on only one half (the young half) of the whole scale.

The observance of a full COE, however, disconfirms Clark's theory of lexical markedness, and a funnel effect is now considered to be a weaker form of the COE.

Insert Figure 3 about here

More recently, semantic congruity has received extensive study with remembered stimuli and full or funnel COEs have been found for a wide variety of continua. As a result, researchers consider the SCE to be robust with memorial stimuli, since all studies investigating SCEs with symbolic or remembered magnitudes have obtained either the full or funnel effect. In fact, the size of the effect (200-500 msec) is quite large when compared to base rate (Baranski & Petrusic, 1991; Petrusic & Baranski, 1991), where base rate is the average RT over all stimulus categories.

Many researchers have been unable to find a SCE for purely perceptual stimuli, such as square size (Marschark & Paivio, 1981), and circle size (Banks, Mermelstein & Yu, 1982), despite the fact that Audley and Wallis (1964) originally obtained SCEs with perceptual stimuli. The inability to obtain a SCE for perceptual stimuli led Banks et al. (1982) to conclude that perceptual and memorial based information were processed

differently. Earlier results obtained by Audley and Wallis (1964) and Wallis and Audley (1964) were dismissed by Banks et al. (1982) as a consequence of near-perfect memory for a limited number of stimuli. Furthermore, Banks and his colleagues attributed research findings by Ellis (1972), who had used complex visual stimuli (i.e., photographs of faces), to symbolic knowledge of facial and/or physical characteristics.

Subsequent attempts by Petrusic and Baranski (1991) to replicate the Banks et al. (1982) findings using circle size also failed to obtain significant SCEs for perceptual stimuli when the tests had insufficient statistical power. However, upon averaging over several experiments, in order to obtain sufficient power, statistically reliable effects of the order of 20-30 msec were clearly evident.

In addition, these researchers attributed the lack of SCE to the use of supraliminal (errorlessly discriminated) comparisons and small sample sizes. Petrusic and Baranski (1989) used comparisons with varying levels of difficulty in order to obtain high error rates. They were successful in obtaining large SCEs for three different stimulus conditions (length, heaviness, and horizontal visual proximity). Additional research yielded similar findings (Baranski & Petrusic, 1992; Petrusic, 1991). Consequently, Petrusic and Baranski (1989) reported that although the SCE for supraliminal (errorless) perceptual discriminations is minimal (in the magnitude of 20-30 msec), a

large effect is easily obtained for perceptual comparisons when performance is not errorless (100-200 msec). Thus, SCEs are consistently found for both perceptual and memorial stimuli, albeit with different magnitudes.

Since SCEs are now considered to be robust for comparative judgements using differing stimuli and methods, it seemed reasonable, therefore, to expect that the current research would also obtain such effects using complex perceptual stimuli (photographs of faces), on an age continuum. A SCE was anticipated between choosing the younger and choosing the older of pairs of faces of different ages. Specifically, the following predictions were made:

1. Time to choose the younger of two young stimuli would be faster than choosing the older of two young stimuli.
2. Time to choose the older of two old stimuli would be faster than choosing the younger of two old stimuli.

Although this research may appear similar to that conducted by Ellis (1972), since both investigate the COE using photographs of faces as the stimuli, the current research differs in several important ways. Ellis (1972) did not investigate whether the age of the individual subject had any effect upon the COE, nor did he make any attempt to control for background noise of the photographs (e.g. contextual clues). Both factors will be taken into consideration in the current research since the literature on aging indicates that the age of the subject will have an

effect on RT and, furthermore, the existence of background contextual clues may influence the perception of the age of the stimuli faces. Also, Ellis used only two categories of faces: children and adults. The research conducted here will use seven different age categories, ranging from infants to 100 years.

In addition, and most importantly, Ellis did not examine the locus of the crossover point of the SCE. The current research, on the other hand, was designed to directly investigate the SCE crossover, referred to here as the point of intersection (POI), and to determine whether the POI could be utilized as a quantitative index of psychological/subjective age. No evidence was found in the research literature that this had been previously investigated. Furthermore, with the exception of studies examining the funnel effect, no research was found that directly studied shifts in the POI. The following post hoc observations, however, have been reported.

Wallis and Audley (1964) observed that the intersection point was "somewhat below the geometric mean of the series of frequencies used" (p.121), and concluded that the POI is the bisector of the stimulus range. This interpretation, however, cannot identify the conditions nor make predictions as to when a funnel effect or a full COE will occur. Furthermore, stimulus range theory does not explain why the funnel effect is reversed for the first stimulus in a pair, for a sequential auditory tone task (Wallis & Audley, 1964).

More recently, Petrusic and Baranski (1989) obtained a reversed funnel effect (i.e., 'lighter' was the unmarked comparative) for the first block of trials, but not for the second block of trials (where a full COE was obtained), using the same stimulus range for both blocks of trials. This finding presents a problem not only for the theory of lexical markedness (since a SCE magnitude of zero occurred for the heavier as opposed to the lighter stimuli), but also for Wallis and Audley's (1964) explanation of adaptability to stimulus range for which a reversed funnel effect should not occur. Thus, Petrusic and Baranski (1991) established that the POI need not necessarily bisect the stimuli range. By way of explanation, these researchers postulated that subjects must be able to regulate the location of the reference point (as activated by the instruction) according to "values stored in long-term memory, reflecting tacit knowledge about [both] the dynamic ranges of a variety of sensory continua, and the perceived within-session range" (Petrusic & Baranski, 1991, p. 449). In other words, the bisector may initially be related to the individual's subjective locus on the entire 'young-old' continuum in memory (e.g., where age 50 and under is considered young and age 100 and over as old, the bisector would be age 75), where Min. and Max' represent the theoretical extremes along the experimental continuum (e.g., age 50 and 100, respectively). This means that initially the subject uses these values of Min. and Max' as the effective reference

points I_0 and I^0 invoked by the instruction 'young' or 'old' respectively, which must fall somewhere outside the stimulus range boundaries Min. and Max'. Then as the subject becomes more familiar with the experiment, he or she adapts to the stimuli range in the context of the experiment, and is able to shift the position of the reference points (I_0 and I^0) to outside the boundaries associated with the experiment (see Figure 4).

Insert Figure 4 about here

Figure 4a represents the two polar end points for an age continuum (from birth to over 100 years). In this example, the subject only encounters stimuli of people aged between 50 and 100 years (Min. and Max'). As indicated above, subjectively the subject considers age 50 to be 'young', and age 100 to be 'old'. In this case, her subjective reference points (I_0 and I^0), activated by the instruction, move to coincide with Min. and Max' and result in a POI (i.e. bisector) of 75 years. A full COE could be obtained.

Now consider presenting additional stimuli of people, ranging in age from 0 to 100 years. As the subject becomes familiar with the range of the stimuli in the experiment, the subject adjusts the reference points (I_0 and I^0), to outside of the minimum (Min.) and maximum (Max') of this stimulus range, as indicated in Figure 4b. The mid-point (i.e. POI) is the bisector

of the contextual stimulus range (i.e. 50 years); thus we observe a shift of POI from 75 years to 50 years. This occurs independently of the age of the subject.

The resulting conclusion of a 'contextual range shift' seems plausible, since it can accommodate differences in the data of obtaining either a funnel or a full COE. Based on their data, Petrusic and Baranski (1989) would predict that either a full or funnel effect could be obtained at the outset of the experiment, depending on subjective reference points. If the subjective and experimentally induced reference points coincide (as indicated in Figure 4a), a full COE will be obtained in the first block of trials; otherwise, a funnel effect will be observed. If the subjective and experimentally induced reference points do NOT coincide, then a full COE will only occur in subsequent blocks as the subject adapts to the stimulus range (experimental context). This theory can also accommodate research findings of a reversed funnel effect, since no assumption of lexical markedness is made. Thus, the type of COE (full, funnel, or reversed funnel) can differ for each individual depending on the location of the subjective reference points along the continuum, based on knowledge and/or experience with the stimuli and the task. Unfortunately, Petrusic and Baranski (1989) did not directly study the POI, hence no specific predictions as to shifts in the locus of the bisector within subjects were tested.

The present study directly investigated the locus of the

POI as a possible index of a persons subjective position along a continuum. Using an age continuum, then, it was proposed that the POI would shift as a function of the individual's subjective age, reflecting the subject's psychological age. For example, the following could occur:

POI for $Y < M < O$,

where Y = younger, M = middle age, and O = older individual. Several alternatives as to how this effect could occur and the form it would take are presented below. Increases to the size of the SCE magnitude were assumed to reflect a slower rate of accruing information associated with increased task difficulty.

ALTERNATIVE THEORETICAL PERSPECTIVES: AGING and SCEs

The following predictions were proposed based on the literature on aging, and the psychophysical research on semantic congruity effects (SCEs) which includes predictions about the magnitude of the SCE and the SCE based POI.

First, the literature on aging would predict longer RTs for both instructions for older individuals, reflecting slowing motor abilities (Corso, 1981). This main effect of age would be reflected in a change in the RT intercept, where the entire SCE would shift upwards as age increases (see Figure 5). However, slowing in physical RT alone would not predict a change in the magnitude of the SCE, or shifts in the locus of the POI deemed to reflect differences in psychological age.

Insert Figure 5 about here

Second, the literature on aging would also predict an increase in COE magnitude, which is deemed to reflect a decreasing scan rate, or slowing mental processes (Sternberg, 1975). A recent evidence accrual theory formulated by Petrusic (1991) would suggest that slowing mental processes are reflected in a slower accrual of information due to a slower sampling rate. Petrusic (1991) assumes that sampling rate will decrease (i.e., get slower) as the distance between the activated reference point and the stimulus pair increases. Thus, when the instruction is incongruent with the location of the stimuli pair along the continuum, more time is required to reach the accrual criterion. Based on this evidence accrual theory, a slower sampling rate would correspond to an increase in the size of the magnitude of the SCE (see Figure 6), and individuals of differing ages should obtain different COE magnitudes because the accrual rate based effect would presumably increase as an individual ages. As a result, both the literature on aging (slowing mental processes) and the psychophysical literature (slower sampling rate) would anticipate that the COE would be more pronounced for older individuals.

Insert Figure 6 about here

Third, classical lexical markedness theory would predict that the COE would shift towards the 'marked' end of the continuum ("younger") for all ages (as previously illustrated in Figure 3). The size of the magnitude should be uniform for all ages, because the effect is a direct result of a bias to respond faster for one comparative (i.e., unmarked) over another.

A reversed funnel effect may result from markedness becoming more ingrained with age (i.e., the question 'older?' is more familiar, and thus requires less space in memory). Another possibility is that a markedness effect reflects differing 'marked' comparisons as a function of age. That is, the 'unmarked' form of the comparative will be "older" for young subjects, but for old subjects the 'unmarked' form will be "younger", relative to their own age. In either situation, middle aged subjects should produce a full COE since they are placed in the middle of the age range, with neither comparative more influential than the other. This will result in different POIs for each age group. This type of result would provide support for the contextual range shift theory, which can accommodate funnel and reversed funnel COEs.

To summarize, both the literature on aging investigating slowing mental processes, and the literature on contextual range shift, anticipate differences based on age. However, each literature area does not make the same prediction about the congruity magnitude and the locus of the POI. For example,

Figures 5 and 6 indicate the results that would be anticipated based on the literature on aging, as observed on the 'y' axis as changes to the RT and the magnitude of the COE as a function of age. No changes to the POI on the 'x' axis are predicted.

Contextual range shift theory, on the other hand, implicates different loci for the POI, depending upon the locus of the initial subjective reference points on the continuum being investigated. If the POI is the bisector of the stimuli range, as stated by Wallis and Audley (1964), then the position of the activated subjective reference points along the continuum should have no differential effect on the POI. Instead, the results will look like classical lexical markedness (funnel effect) as indicated in Figure 3, where any shift to the POI will be consistent across age. Contextual range shift theory, however, assumes that the POI is initially the bisector of the subjective reference points along the continuum (as activated by the instruction). That is, these subjective reference points change according to the Min. and Max^r of the stimulus range encountered; thus, the POI can shift as a function of the experimental context. Since subjective reference points are considered to be flexible and change according to the experimental task, the POI will subsequently shift in the appropriate direction in order to bisect the stimulus range associated with the experiment.

Several alternative theoretical possibilities were presented above in an attempt to account for the underlying

psychological processes involved in the SCE. A model of SCE primarily has to account for the various identified properties associated with the operation of the comparison process (Baranski & Petrusic, 1991; Petrusic, 1991) with both perceptual and remembered stimuli. These include: gradedness, difficulty, and the speed accuracy tradeoff function (SATF). In addition, experimental results obtained by Petrusic (1991) and Petrusic and Baranski (1989) for perceptual, and nearly errorlessly discriminated stimuli, imply that a theory of SCE must also be able to accommodate COEs of varying magnitudes for both memorial (see Petrusic & Baranski, 1991) and perceptual stimuli (Petrusic, 1991), and differential types of COEs (i.e., full, funnel, and reversed funnel) with differing POIs.

The gradedness effect refers to the continuous form of the data, as opposed to a step-like appearance. Earlier research speculated that the form of the SCE could be either (a) found only for the most extreme stimuli; (b) the effect would be the same for stimuli at the same level, or (c) a gradual, graded effect that increases systematically along the continuum, where the POI is always graded about the bisector of the stimuli range. While all three possibilities yield a crossover or SCE, the latter (gradedness) property is now well accepted for full or funnel SCEs (Banks & Flora, 1977; Jamieson & Petrusic, 1975). A step-like function only occurs if the stimuli pairs are not equally spaced along the continuum.

Changes in the level of difficulty yield an increase in both overall RT, its variability and in the accuracy of the comparisons and the SCF (Petrusic, 1991; Petrusic & Baranski, 1989). However, with stimulus pairs along the continuum equated for difficulty, the magnitude of the COE becomes larger as you move toward continuum extremity (exhibiting a gradedness characteristic).

Speed accuracy tradeoff functions (SATF) also place important constraints on theories of SCE. For example, Petrusic (1991) shows that the size of the SCE decreases for speeded responding and, as times decrease under speed conditions, error times become faster than correct RTs; concomitantly, SCE for error responses is less than for correct responses. However, under accuracy conditions, this relationship (micro tradeoff) between correct and error times is reversed: error times are longer than correct times and the SCE is larger for error responses than for correct responses.

Since SCEs of varying magnitudes have been obtained for both memorial and perceptual stimuli, a model should not only be able to accommodate both types of processes, but also account for larger effects typically obtained for symbolic/remembered stimuli.

THEORIES OF SCE AND SUBJECTIVE AGE

Only two SCE models are clearly relevant to the current thesis, since they can account for the majority of the above-

mentioned properties and because of their ability to make predictions about the locus of the POI. These are: Semantic Coding Theory (SCT) and Reference Point Theory (RPT). If the data fit the predictions about the locus of the POI, it was proposed that one of these models might emerge as a general theory of the psychological aging process.

Semantic Coding Theory

Banks (1977) stated that comparative judgement tasks involve three global sequential processing stages: encoding, choice, and response. In the first stage, the perceived stimuli pair and the instruction are converted into discrete codes. This is done by the processing mechanism through the generation of codes from symbolic information stored in long term memory (i.e. the data base). For example, presentation of a pair of photographs of relatively young people, x_1 and x_2 , should result in the codes Y^+ and Y , respectively, whenever alternative x_1 is indeed younger than x_2 . Similarly, if x_1^1 is clearly younger than x_2 , then that photograph would be coded as Y^{++} . The presentation of a particular instruction initiates a search for stimulus codes matching that specified by the instruction. For example, presentation of the instruction 'YOUNGER' initiates a search for the stimulus with the largest Y code; i.e., when x_1^1 and x_2 are presented, the codes Y^{++} and Y^+ are activated and x_1^1 is chosen.

In the second stage, the codes for the stimulus pair (e.g. ' Y ' and ' Y^+ ') are compared to the instruction code (e.g.,

'YOUNGER?' coded as 'Y+?'). If a match exists (i.e. 'Y+' matches 'Y+'), the response stage (stage 3) can be initiated immediately. However, if there is a conflict and no match occurs (i.e. stimuli are coded as 'Y' and 'Y+', but the question is coded as 'O+?'), then the processing mechanisms must manipulate the stimulus codes until they match the comparative code. That is, Y/Y+ must be converted to O+/O, at an additional increase in overall response time. Banks (1977) postulates that the extra time required for code transformation gives rise to the SCE. In other words, SCE occurs as a result of post-decisional matching or mismatching of stimulus and instructional codes; therefore, the locus of the SCE is in the final response selection/execution stage.

A desirable property of this model is that it can accommodate the funnel effect if one of two assumptions are accepted (Banks, Clark, & Lucy, 1975). First, these researchers proposed that the funnel effect could be "simply a crossover effect with one of the two responses speeded up overall" during response selection or execution (Banks, Clark & Lucy, 1975, p. 37). This explanation is similar to that proposed by Lexical Markedness Theory, except that Semantic Coding Theory does not make any specific predictions about the direction of the effect. Thus, a shift in the POI could occur in either direction. If we accept this assumption, SCT can accommodate the hypothesis that the POI will shift differentially as a function of age.

A second possibility offered by Banks, Clark and Lucy

(1975) is that the funnel effect occurs as a result of a higher probability of encoding the stimuli in one direction during the perceptual stage (e.g. the probability of generating an OLD/OLD+ pair of codes may be .80 compared to .20 for generating YOUNG/YOUNG+ codes). Thus, the probability of a response would be greater for one of the comparatives over the other (i.e. in this case, OLDER), which would speed up the matching/translation stage operations. This concept can also accommodate shifts in the POI as a function of age, if we further assume that individuals of different ages have different probabilities for code generation.

Both of these assumptions imply only that the funnel effect (or reversed funnel effect) will result in a change in intercept of one of the slopes, and make no predictions about a change in the rate of processing or rate of code translation. That is, the entire plot will shift downward evenly, because the speeded responding for one comparative will apply equally along the continuum. Although the magnitude of the COE will be increased as a result of a change in intercept for one comparative, SCT would predict a similar magnitude for all ages (once base rate has been controlled for). Thus, a differential magnitude as a result of differential mental processing or evidence accrual rate, would present a problem for SCT.

Semantic Coding Theory is also sufficiently flexible to permit differential coding with age. Intuitively, it is clear

that a very young person is quite likely to view a 30-year old person as "old". On the other hand, a 70-year old may well view a 30-year old person as "very young". SCT captures these intuitions quite well. If, in fact, such age dependent codes occur, then they will be reflected in the pattern of SCEs and the POI should shift towards the old-end of the continuum with increasing age of the subject. SCT, therefore, predicts that the POI is at the boundary between the "young" and "old" categories. This assumption was tested using both choice discrimination and category-boundary tasks. The relationship between the POI and the category boundary in a single stimulus "young-old" categorization task can be tested directly, since it accesses the codes "young" or "old" directly. If the category boundary changes as a function of age, it must be the case that the POI will also shift as a function of age because the POI is the bisector of the two categories, as determined by the subject. The category boundary and the POI, therefore, should be the same. This finding would provide strong support for the use of the POI as an index of psychological age; since both the discrimination and category boundary tasks require perception, learning and memory in order to make a decision and the speed and accuracy of the decision is deemed to reflect a person's ability to adapt to the environment.

Reference Point Theory (An Evidence Accrual Model)

The discrepancy ratio model, originally proposed by

Jamieson and Petrusic (1975) to explain comparative judgement, was later extended as a reference point theory (Holyoak, 1978). The discrepancy ratio model assumed two ideal points (I_0 and I^0), one at each end along any continuum. These ideal points exist in long term memory, but temporary dynamic ideal points (I_1 and I^1) may be generated according to the stimulus range context of the experiment (Min, and Max^{*}) (Petrusic & Baranski, 1991). (An example, of this model has already been given in the discussion of COEs, and an example provided in Figure 4).

In this model, a discrepancy ratio (R) can be computed for each stimulus pair; the value of this ratio determines which response we will make. For example, suppose we have a stimulus pair, X and Y , where $X > Y$ along an age continuum. Let I_0 represent the ideal point for 'young' and I^0 represent the ideal point for 'old'. The distance of stimulus x from the ideal point initiated by the comparative 'YOUNGER?', denoted $d[I_0, s(x)]$, is compared to the distance of stimulus y from the same ideal point, denoted $d[I_0, s(y)]$. This provides us with a ratio, $R = d[I_0, s(x)]/d[I_0, s(y)]$, which is relative to some criterion (C), where $C = 1$ in the unbiased case. Thus,

x is younger than y if and only if $R \leq C$

y is younger than x if and only if $R > C$.

For example, on an age continuum

Substituting,

$$R = 4 - 0 / 7 - 0 = 4/7 = .57$$

Since $R = .57$, which is < 1 , we determine that x is the younger of the two stimuli.

On the other hand, if we initiate the 'OLDER' reference point where the reference point is now I^0 we can see that

$$R = d[I', s(x)] / d[I', s(y)]. \quad \text{Thus,}$$

x is older than y if and only if $R \leq C$

y is older than x if and only if $R > C$.

Substituting,

$$R = 4 - 12 / 7 - 12 = -8/-5 = 1.6$$

In this case, $R = 1.6$, which is > 1 , which means that y is older than x .

The length of time required to make this decision, after the reference point has been activated by the instruction, will be a monotonic decreasing function (f) of the distance R is from its criterion, C , plus some positive constant (A) not resulting from decision processing (e.g. physical response time), such that

$$RT = f [D (R,C)] + A.$$

In other words, RT is dependent on the direction of the comparative, and not on the stimulus representations (assuming the stimuli are equated for difficulty). The closer the stimulus alternatives are to the ideal or reference point, the easier the discrimination will be. This results in a smaller discrepancy ratio, and faster Rts (Jamieson & Petrusic, 1975).

RPT was subsequently revised by Petrusic (1991), and placed in the context of an evidence accrual theory. Evidence Accrual Theory predicts that as the discrepancy ratio decreases, the rate of evidence accrual will increase; therefore, RT will be faster. Petrusic (1991) further hypothesized that "the semantic congruity effect occurs at the level of each evidence accrual event" (Petrusic, 1991, p. 15), and the evidence accrual process continues until some decisional criterion is reached (Petrusic, 1991). This means that the closer the stimulus alternatives are to the reference point activated by the comparative (a congruent condition), the faster this criterion will be reached. Conversely, in the incongruent condition, information about the stimulus pair will be accrued at a slower rate; thus, the time required to reach the same criterion will be longer. It should be noted that the decisional criteria associated with the total evidence accrued regulate the speed and accuracy of the response, whereas the unbiased or biased decisional criteria (C) is a criterion set at the level of each accrual and regulates the markedness-like effects.

Predictions about the locus of the POI in RPT can be made by assuming flexible decisional criteria regulating markedness-like effects (Jamieson & Petrusic, 1975), flexible/differential evidence accrual sampling rates (Petrusic, 1991), and/or flexible reference points (Petrusic & Baranski, 1989). Each of these assumptions will be addressed in turn.

As discussed in the context of 'contextual range theory', the COE will be symmetric about the bisector of the two reference points when using an unbiased decisional criterion ($C=1$) (Jamieson & Petrusic, 1975). This means that a full COE will be obtained. On the other hand, funnel effects can be accommodated if the criterion parameters are biased; that is, C is not equal to 1. The two decisional criteria will result in differences in the locus of the POI. Thus, it is assumed that the decisional criteria are flexible. Unfortunately, it remains unclear how a flexible biased criterion (i.e., $C \neq 1$) would be able to predict when a funnel effect would occur as opposed to a reversed funnel effect. Presumably, each reference or ideal point would have its own criterion (e.g., C_0 and C^0).

Second, if the evidence accrual criteria is flexible, the subject can adjust the amount of information accrued depending upon the speed or accuracy conditions imposed. Congruity effects would be smaller under speeded conditions because the criterion is lower, resulting in faster RTs and smaller SCE magnitudes. The converse would be observed under accuracy conditions. Changing the sampling rate will affect the magnitude of the COE, where the COE magnitude will increase as the sampling rate gets slower. A change in the sampling rate could also shift the locus of the POI, where the shift could be a function of the familiarity with the comparative. For example, if the rate of accumulating information was faster for one comparative over

another, then the POI would occur at a different point along the continuum than if both comparatives invoked the same rate of evidence accrual. The POI shift, however, should not occur directly as a function of the individual's age. This is the major difference between RPT and SCT.

Third, flexible reference points were also implicated in the contextual range shift theory proposed by Petrusic and Baranski (1989), as discussed earlier. For example, ideal reference points along a continuum (I_0 and I^0) are activated from long term memory upon presentation of the first instruction. During the course of the experiment, the subject dynamically adjusts these reference points (I_1 and I^*) to reflect the youngest (Min.) and oldest (Max^*) stimuli in a given block of trials (e.g. see Figure 4). RPT predicts a funnel effect when the bisector of the reference points in long term memory (invoked by the instruction) is greater than Max^* , such that $[(I_0 + I^0)/2 > Max^*]$ (Petrusic & Baranski, 1989). Then, as the subject becomes familiar with the contextual range of the task, she shifts I^0 towards Max^* , and obtains a full COE. Although, these researchers did not explicitly state how a reversed funnel effect could be obtained, presumably it would occur when the bisector of the reference points in long term memory is less than Min^* , such that $[(I_0 + I^0)/2 < Min^*]$.

Despite the above explanations of obtaining a funnel effect (and hence a shift in POI), RPT predicts that the POI will not

necessarily shift as a function of the age of the individual. For example, RPT asserts that for the set of stimuli used, the activated reference points will fall outside the range of stimuli encountered. This occurs because some compromise between the contextual range of stimuli and the values stored in LTM are presumed to control the subjective reference points, and not the age of the subject. It is this latter point that differentiates the two SCE theories. The absence of differential POIs as a function of the individual's age will provide support for RPT. On the other hand, this presents a problem for SCT, because SCT predicts that the POI is at the boundary between the 'young' and 'old' categories, which should shift with age, as previously mentioned. Should shifts in the POI be observed, support for SCT will be obtained. RPT could only accommodate shifts in the POI as a function of age if we make the following auxiliary assumption: that the underlying age continuum is perceived differently as a function of age). In other words, presumably the representation in memory of an age continuum has changed as a function of the subject's own aging. For example, we might expect the category boundaries to be subjectively stretched near the subject's own age, and more distant boundaries would be compressed. This type of effect has been observed by Ager and Dawes (1965) for paired comparisons of attitude statements. Subjects had significantly more confusions among stimuli further from their own subjective position.

For the purposes of this thesis, Semantic Coding and Reference Point theories were examined using an age continuum for several reasons. First, these models can make specific predictions about the magnitude of the COE, and shifts in the locus of the POI as a function of age.

Secondly, these theories may lend themselves to understanding underlying psychological aging processes, since they can accommodate individual differences in subjective or psychological reference points on a continuum, such as aging, or in the codes generated in memory based on one's own age. The terms subjective and psychological are used interchangeably in this thesis, since both are assumed to refer to underlying psychological processes.

Thirdly, if we accept that discriminations along an age continuum provide information about the comparative process of subjective (psychological) age, it seems equally plausible that gaining information on the underlying structure of subjective age for an individual will provide some information about that individual's own subjective (psychological) age. Thus, it was hypothesized that a moveable POI could serve as an index of psychological age.

Finally, no assumptions or restrictions are made about the linearity of the underlying scales in these SCE models. Further, these psychophysical tasks are considered to be multidimensional because they involve each of the three properties identified with

psychological age: perception, learning, and memory. For example, the visual stimuli of the task must first be perceived, and then the experimental range of the stimuli must be learned (i.e. Min. and Max') in order to adjust the ideal reference points (I_0 and I^0), or to invoke the relevant codes, in memory. In summary, the following hypotheses will be tested:

1. Overall, comparative judgement response times (CJRT) will increase as a function of age;
2. SCE magnitude will vary as a function of age;
3. Both the POI and the Category Boundary will vary as a function of age; and
4. the POI and the category boundary will coincide.

To test for SCE, stimuli along an age continuum were required. Experiment 1 was designed to obtain two male and two female digitized photographs of faces into each of seven non-ambiguous categories for use in Experiment 2.

In Experiment 2, a psychophysical discrimination task (comparative judgement) was used to obtain indices of SCE (the SCE magnitude and locus of the SCE based POI) and the relationship of these indices to chronological age. In addition, the Category Boundary was obtained in a binary age discrimination and related to both the SCE indices and age.

EXPERIMENT 1: CATEGORIZATION TASK

Phase 1a

Method

Subjects

10 undergraduate students registered in an introductory psychology class at Carleton University received course credit for participation.

Stimuli

151 black and white photographs of Caucasian faces, full face, with no facial hair, glasses, or visual disfigurement, were taken using a Minolta 7 camera. An aperture setting of 5 was used throughout, with the electronic flash set at 60, at a distance of approximately 9 feet. A white screen was used as the backdrop for all photographs in order to eliminate any background noise.

Procedure

After signing an Informed Consent form, subjects were asked to categorize 151 photographs of faces into different age groups; subjects were not told how many categories to use. This phase was designed to determine the number of age categories required for Experiment 2. Participants were verbally debriefed for this and all subsequent phases of the experiment.

Results

This phase of the experiment yielded almost as many categories as there were subjects. Each subject produced a different number of age categories, ranging from 8-20 categories, with only one overlap (11 categories). Since the focus of this research was not on categorization, it was decided to abort this

phase of the experiment and impose an arbitrary number of categories on subjects.

Phase 1b

Method

Subjects

30 additional subjects were recruited from the same population as Phase 1a.

Stimuli

The stimuli consisted of the same set of 151 photographs of faces as that used in Phase 1a.

Procedure

A 7-category restriction was imposed on subjects, based upon Miller's (1956) notion that we can errorlessly identify stimuli in approximately seven categories.

Participants were asked to place 151 photographs of faces into the 7 age-categories, but since the purpose of this phase was to obtain 7 unambiguous sets of photographs without experimenter bias, no age-range per category was provided. Once the task was completed, subjects were then asked to provide an age-range for each of the previously sorted categories.

Results

Some subjects used ages associated with various educational transitional stages as their decisional criteria; this may simply have been the result of testing individuals currently involved in attaining further education. Other subjects identified the faces

with family members and friends ages (i.e. own age range, parents, grandparents).

The following seven categories were the most frequently chosen age ranges:

1.	0-5	($\bar{M}$ = 1.25)	5.	40-59	($\bar{M}$ = 55.38)
2.	6-11	($\bar{M}$ = 5.00)	6.	60-69	($\bar{M}$ = 68.81)
3.	12-19	($\bar{M}$ = 13.25)	7.	70+	($\bar{M}$ = 88.25)
4.	20-39	($\bar{M}$ = 28.03)			

It should be noted that the Mean age of the photographs is based on the actual age of the person in the photograph and may not correspond to the category age, which is based on the perceived age of the photograph by the subject.

In order to verify whether the same task was feasible using imposed-categories, to ascertain whether the categories made sense to the participants, and to determine whether any additional problems existed that may have been overlooked, phase 1b was replicated utilizing the above age-ranges associated with the seven age categories.

Phase 1c

Method

Subjects

12 additional subjects were recruited from the same population pool as the previous two phases.

Stimuli

The stimuli were identical to those used in the previous

phase of this experiment.

Procedure

The above-mentioned categories were written on two-inch post-it notes and adhered approximately two inches apart to a wall six inches above a table. This eliminated the need for memorization of the age-ranges associated with each category.

Subjects were asked to place each of the photographs into the appropriate category using the age-ranges provided.

Results

Most subjects reported that they found the task easy, and that the categories were either "useful" or "appropriate". One subject, however, did indicate that she found the task hard; the reason given was that she had difficulty in choosing between certain categories at their boundaries.

Since subsequent research required subjects to make various types of judgements based on digitized faces on a computer screen, Phase 1c was replicated using the same images to ensure the computerized task was roughly equivalent.

Phase 2

Method

Subjects

20 additional subjects were recruited from the same population as Phase 1.

Stimuli

151 photographs of faces were digitized using optical

processing equipment, which converted the analogue photographic images into a series of digital representations. The photographic image was digitized using an RS-170 video camera, light board, and a FG-100 Frame Grabber graphics board with EGA graphics capability, installed in an IBM-AT type computer. Computerized images (520 x 480 bytes in size, with 6 bits intensity level per byte) were saved on individual floppy disks. A computer program, written in Turbo Pascal by this author with assistance from Rick Mallett of Carleton University's Computer Services Department, was necessary to translate the machine coded image from the IBM-AT type computer hooked up to the digitizer (with EGA colour graphics capability) to an IBM-XT type computer (with Hercules monographics capability) which was located in a separate laboratory.

The effect of transferring data from EGA colour graphics mode to Hercules monographics mode resulted in some loss of pictorial information. In addition, the effect of transferring from EGA graphics (with a display ratio of 3 to 4) to Hercules graphics (with a display ratio of 2 to 3) caused some visual distortion of the image. While most of the distortion was eliminated by 'stretching' the image in the opposite direction, some residual effect remained. However, since this residual effect was minimal and was constant for all images, the resultant images were deemed acceptable for use in the subsequent computerized tachistoscopic experiment.

The digitized images were then reduced in size to 10 1/2 mm wide x 7 1/2 mm high, since Experiment 2 required the stimuli to be presented two at a time. The quality of some of the faces was quite poor as a result size reduction, and these were eliminated from the study. 114 of the 151 images remained, 14 of which were used as practice trials (1 male and 1 female per age category). A pilot study with a 68-year old female indicated that the age of the faces for the remaining images could be discerned. An example of the stimuli can be found in Appendix 1.

Procedure

114 digitized reduced-size faces were randomized prior to commencement of the experiment (14 practice trials, 100 actual trials). The age ranges and associated category numbers were presented at the top of the computer screen two seconds prior to displaying a face, and remained on the screen until a category selection had been made. This helped eliminate the need to memorize the age categories, and also served as a preparatory signal that a face was about to appear.

Each face was presented sequentially in the centre of the screen, viewed from an approximate distance of 2 feet, and remained on the screen until a category selection had been made. The screen was then cleared. After a short delay, the age categories reappeared, followed by another face, etc.

Subjects were asked to place 114 faces into seven age categories, entering their data directly into the computer using

the number keys at the top of the keyboard.

Results

A breakdown of Face by Category was done using SPSS-X. Faces to be used in the subsequent discrimination task were selected from the population of faces based on the highest concordance between-subjects, until 4 male and 4 female faces per age category ($8 \times 7 = 56$) were obtained. 28 of the 56 faces (2 male and 2 female per category), with the highest percentage agreement (average of 85%), were identified for use as trial stimuli; the remaining 28 images were selected for use as practice trials.

Discussion

Experiment 1 was designed to eliminate ambiguous or overlapping stimuli (i.e., not clearly in one category). It was hoped that this approach would increase the likelihood that the categories would be evenly spaced on the continuum and, therefore, control for the influence of difficulty on the COE. This was deemed necessary because variation in difficulty of discrimination between stimuli in adjacent categories causes variations in the magnitude of the COE, and can obscure shifts in the POI.

EXPERIMENT 2: DISCRIMINATION TASK

Method

Subjects

45 subjects of varying ages were recruited from Carleton

University psychology courses, The Good Companions Seniors Centre, and the general population in the Ottawa area.

Subjects first signed an informed consent letter, then were pre-screened to establish normality of visual perceptual ability, using two memory and one copy trial of the Taylor (1969) Complex Figure (Appendix 2). Scoring was done using Tombaugh's (1989) itemized scoring system (Appendix 3), and 7 subjects who did not meet the criteria were eliminated from subsequent analysis. That is, those subjects whose scores fell below the 10th percentile on either trial. Four individuals in the Young age group failed the second memory trial, whereas three individuals in the Senior age group failed the copy trial. One Young subject was excluded because his data contained several empty data cells, and one subject was excluded because he was considered too young for the Senior age group and too young for the Young age group (i.e., age 63). 36 subjects ranging in age from 19 to 75 years remained, and were divided into three age groups, each consisting of 7 females and 5 males per group. Group 1 ranged from 19-24 years (Mean=21); Group 2 ranged from 30-45 years (Mean=40); and Group 3 ranged in age from 68-75 (Mean=71).

Stimuli

Pairs of faces (10 1/2 mm x 7 1/2 mm) were simultaneously presented in the centre of the computer screen, approximately 2 pixels apart, with a contrasting border of 1 pixel in width. The faces consisted of 2 females and 2 males in each of 7 non-

overlapping categories. The two stimuli to be compared were taken from adjacent categories, in the following combinations: male/male; male/female; and female/female. Stimuli were controlled for position order effect (i.e. left/right; right/left).

Procedure

1. Comparative Judgement

A practice session of 18 trials (6 adjacent categories by 3 gender pair combinations), was followed by 4 blocks of 96 trials each. Stimulus pairs were randomized between blocks to ensure that each category and gender combination were equally represented per block, and then randomized within block. The order of block presentation was balanced over subjects according to a Latin Square design.

The question, either "Younger" or "Older" was presented randomly at the top of the computer screen, followed 2 seconds later by a pair of randomly selected digitized faces. Subjects were asked to make a perceptual discrimination, as per the above question, and indicate their choice using one of two buttons on a mouse. Response time and accuracy data were recorded automatically in a computer data file.

2. Binary Categorization

Following the discrimination task, subjects were provided the opportunity of taking a short break before being asked to identify whether each of the previously-presented faces was

'young' or 'old'. In this task, each face was presented sequentially in the centre of the computer screen, and the response was again made via a two-button mouse. This was done to determine the perceived age of transition from young to old (i.e. the category boundary), which should correspond to the POI obtained in the discrimination task. Each face was presented once. Subjects were appropriately debriefed.

Results

Based on recommendations presented by Pachella (1974), very fast RT data (less than 200 msec) were removed from analysis because they are believed to be the result of anticipation. Very slow RT data (greater than 9999 msec) were also removed because they have a tendency to cause a positively-skewed tail in the RT distribution (Pachella, 1974).

1. Comparative Judgement

No significant difference was found between position order effect (right/left vs. left/right), thus the data were pooled over this nuisance factor.

An analysis of variance (Anova) was conducted on Mean response times with Age Group and the Gender of the Subject as the between-subject factors, and Category Pair, Instruction, Block, and Gender of the Face in the picture as the within-subject factors. Significance levels were established by using Greenhouse-Geisser epsilon adjusted degrees of freedom throughout, although the degrees of freedom reported are those

defined by the design.

The Anova yielded a significant main effect for the three Age Groups ($F(2, 30) = 4.03, p < 0.0281$), with response times increasing with increasing age. Figure 7 provides a view of these effects of Age Group at each level of the Category Pairs. As can be seen in Figure 7, the Category Pairs differed reliably ($F(5, 150) = 10.85, p < 0.00001$) and these effects were invariant over Age Groups.

Insert Figure 7 about here

Importantly, the interaction between Instruction and Category Pair was statistically reliable ($F(5, 150) = 5.82, p < 0.0004$). Figure 8 plots the semantic congruity index (i.e., RT difference for each level of category pair) separately for each of the three Age Groups. While it is clear that congruity effects are present for each of the three Age Groups, the three-way interaction involving Age Group, Instruction and Category Pair failed to obtain statistical significance ($F < 1$).

Insert Figure 8 about here

Nevertheless, at a qualitative level two points are evident in the plots in Figure 8. First, the largest congruity effect is obtained with the senior subjects, who responded most slowly

overall. Second, the crossover point (POI) is also evident in Figure 8; that is, the point on the age continuum where the semantic congruity effect is zero for each of the Age Groups. The POI is ordered by age: the Young Age Group has a POI that falls between Categories 2 and 3 (i.e., low teens), the POI for the Middle Age Group lies just below Category 5 (i.e., 40-59), and the Seniors Age Group has a POI between Categories 5 and 6 (i.e., approximately age 55).

An Anova also yielded a significant three-way interaction involving Instruction, Category Pair and Gender of the Subject by conventional test ($p < 0.0414$) but not by the Greenhouse-Geisser criterion ($F(5, 150) = 2.38, p > .0601$). As Figure 9 shows, in general Females were faster overall (Mean RT = 2065.6266 ms) than Males (Mean RT = 2236.7135 ms), however, this main effect is not statistically significant ($F(1, 30) = 0.84, p > .3654$). More importantly, congruity effects are clear for both genders. Figure 9 plots Mean RT for Males and Females for both comparatives at each level of Category Pairs. It is also evident that the SCE magnitude begins to pull apart at Categories 5 and 6 for both males and females; however, it is evident that the congruity pattern differs for males and females. The crossover in responding faster for one comparative over the other occurs at Category Pairs 5 and 6 for females, and at Category Pairs 6 and 7 for males. Further, females have more difficulty than males in choosing between the younger of two old faces in Categories 5 and

6 (as one would expect in semantic congruity theory), whereas males have the most difficulty choosing the older of two old faces (which is contrary to semantic congruity theory). Figure 9 also shows differing POIs: the POI for females falls just below Category 5, whereas the POI for males is at Category 6.

Insert Figure 9 about here

In addition to the above effects of major interest, the Anova revealed a significant main effect of Block ($F(3, 90) = 51.60, p < 0.00001$); Mean response times were 2625.6 ms, 2130.3 ms, 1948.1 ms, 1842.0 ms for Blocks 1 through 4, respectively. The main effect of the Gender of the Face in the picture pairs was also highly reliable ($F(2, 60) = 40.79, p < 0.00001$); response was fastest when both faces were male (1993.8 ms), slowest when both were female (2224.1 ms), and intermediate (2194.1) when one face was male and the other female. However, this main effect of Gender of the Face of the picture is qualified by a significant interaction involving Block ($F(6, 180) = 2.40, p < 0.0501$). Figure 10 plots Mean response times as function of Block separately for the three different configurations used. Furthermore this two-way interaction is qualified by a marginally significant three-way interaction involving Age Group ($F(12, 180) = 1.98, p < 0.0502$) that defies interpretation.

Insert Figure 10 about here

2. Error Analyses

Overall, the Young Age Group made the fewest errors (3.76%); this was similar for the Middle Age Group who had an error rate of 3.77% overall. The Senior group had almost twice as many errors than the other two groups (7.28%). Interestingly, the Young Age Group performed more accurately with the older Category Pairs of faces, whereas the Senior Age Group made the most errors and found the task more difficult when choosing between Category Pairs of older faces. The Middle Age Group displayed the most errors for Category Pairs 3 and 5.

Figure 11 plots the percentage of errors at each level of the Age Category Pairs separately for each Age Group. These plots reveal that the Young Age Group make few errors overall Age Category Pairs, and have the most difficulty with the older faces between Categories 6 and 7. The Middle Age Group on average also make few errors, however, their pattern is more variable. This group has the most difficulty between Categories 3 and 4, and between Categories 5 and 6. In addition, the Middle Age Group has by far the fewest errors with the faces in the oldest Age Category Pairs (i.e., Categories 6 to 7). The Seniors Age Group have the largest number of errors overall. Interestingly, on the one hand, they have the greatest difficulty with the oldest Age

Category Pairs of faces (i.e. between Categories 6 and 7) but they have the virtually no errors with the Young faces (i.e., between Categories 1 and 2).

Insert Figure 11 about here

Data from Figure 11 suggest that those subjects in the youngest Age Group are the fastest and make the fewest errors, whereas those subjects in the Seniors Age Group had the longest RTs and almost twice as many errors than either of the other two Age Groups. This finding, however, must be qualified. For example, the perception of the age of the faces is not an absolute. That is, the actual age of the faces was not used in the analysis. Rather, the perceived age of the faces in this experiment were compared to the perceived age category of the faces, as obtained in Experiment 1. Thus, these errors are not exactly inaccuracies; instead, they should be interpreted as inconcordance with subjects from Experiment 1. The dip between Age Categories 4 and 5 are presumed simply to reflect the large age-spread between these two categories.

3. Binary Categorization

An Anova was conducted on Mean response times with Age Group and Gender of the Subject as the between-subject factors, and Age Category of the Face and Gender of the Face in the picture as the within-subject factors.

The Anova yielded a significant main effect for the Age Category of the Face in the picture ($F(6, 180) = 13.78, p < 0.00001$). No other main effects nor interactions were significant. Figure 12, which provides a view of the overall response times at each age category separately for each age group

Insert Figure 12 about here

shows the clear absence of a systematic dependence of these binary responses on Age group

Figure 13 plots the Probability of Response "Old" for the stimuli in each of the Age Categories separately for each Age group. The plots of these psychometric functions are strikingly similar and also show that the Points of Subjective Equality (PSE) (i.e., that point on the x-axis corresponding to the .5 probability of responding "Old") coincide nearly perfectly. Corresponding to the peak response times at category 5, shown in Figure 12, it is clear from the psychometric function that PSEs fall between Categories 4 and 5.

Insert Figure 13 about here

Discussion

The present findings encourage using comparative age judgements to continue the investigation of psychological age.

These preliminary results establish a very general dependence of the POI on the chronological age group for the psychophysical discrimination task. Not all hypotheses, however, were confirmed.

Comparative judgement response times (CJRT) increased as a function of increasing age as predicted, in accordance with the literature on aging, and the evidence accrual theory. These findings suggest that evidence is accrued more slowly with increasing age. This important conclusion follows unequivocally from the fact that response times in binary categorization task do not differ across age groups. Consequently, the main effect of age group cannot be attributed to peripheral input-output processes.

A significant semantic congruity effect (SCE) was found for each age group. However, differential SCE effects, as a function of age group, failed to find statistical respectability despite evidence of their presence; notably, overall congruity magnitude is largest for Seniors, especially with pairs in categories 5 and 6. Perhaps, with sufficient statistical power this three way interaction involving age group, category pair and instruction would achieve conventional statistical reliability. In addition, the failure to obtain statistical significance of this three-way interaction, questions whether in fact the POI's do, indeed differ as a function of age group. However, the clear ordering of these POI's as a function of age clearly support the hypothesis

that the perception of age is dependent upon the age of the judge.

Only partial support was obtained for hypothesis 3. The POI was found to vary as a function of age; however, the Category Boundary did not. The observation that the POI varied for each of the three age groups suggests that the psychophysical discrimination task is sensitive to some aspect of the perception of aging, and lends support for its use in developing an index of psychological age. Variability in the POI provides initial support for Semantic Coding Theory, and suggests that this model might be useful in developing a theory of psychological aging. The Category Boundary task, however, was found to be insensitive to age. These two results taken together, disconfirm hypothesis 4, that the POI and the Category Boundary should coincide, and challenge the Semantic Coding theory.

The finding that the POI increased with age but that the Category Boundary did not is troublesome for both the Semantic Coding and the Reference Point views. According to Semantic Coding theory the category boundary and the POI must coincide because binary categorization reflects long-term memory semantic codes for age and these codes are the basis for the semantic congruity effect. In this study, this is clearly not the case.

On the other hand, in the absence of auxiliary assumptions, Reference Point theory is unable to account for differential POIs with age because this theory predicts that the POI is entirely

dependent upon the within session range, which was the same for all subjects (i.e., all subjects received the same set of stimulus pairs). One way that the Reference Point theory can accommodate age changes to the psychophysical function with chronological age is to assume that the underlying perception of an age scale represented in memory is non-linear. This notion fits with the findings by Ager and Dawes (1965), that the category boundary was subjectively stretched near to the subject's own position on an attitude scale. In the present study, which uses an age continuum, we might expect the category boundary to be subjectively stretched near the subject's own psychological age. It is unclear, though, how this theory can accommodate flexible category boundaries in the discrimination task, yet be resistant to changes in the Category Boundary for the binary categorization task, unless the flexibility in the rate of accumulating information is also task dependent.

These findings suggest that the two psychophysical tasks, although presumed to be directly related, may be tapping different aspects of cognitive functioning. Perhaps the discrimination task, which is indirect, is related to psychophysical aging, and the Category Boundary task is accessing social codes of the perception of aging more directly. This possibility will need to be explored further.

The notion that the two tasks are measuring different cognitive abilities is also supported here by differences between

gender. Evidence of faster RTs and a younger POI for females on the semantic congruity task could be related to differences in longevity, whereas the absence of differences in the Category Boundary could be indicative of social norms of when "oldness" is perceived to begin. An alternative, and perhaps more plausible, explanation might be that females are faster overall when making age discriminations, and hence have a younger POI, reflecting greater familiarity with, and societal emphasis on, finer age discriminations by women. In fact, Posner (1977) found that women are perceived to 'begin to age' earlier than men, and that looking 'young' is considered more important for women than for men by both genders. It seems likely, therefore, that women (forced to be more preoccupied with aging) have a more complex representation of an age continuum in long term memory. On the other hand, the Binary Categorization task only requires the subject to make a more crude judgement (i.e., 'young' or 'old' as opposed to 'youGER' or 'oldER'). Thus, the two tasks could either be accessing different cognitive functions, or indicate that the underlying scale is flexible and task-specific.

A further explanation is that the distance between the middle age categories (i.e. Categories 4 and 5) was too large. For example, while the age range for Category 4 was 20-39 years and the age range for Category 5 was 40-59 years, the Mean age of these categories based on actual chronological age of the person in the photograph was 28.03 years for Category 4 and 55.38 years

for Category 5. For most people, it is very easy to distinguish a 28-year old from a 55-year old. Subsequent research is required to investigate the underlying age scale of a large set of photographs for individual subjects.

A fourth possibility is simply that the entire stimulus range was learned in the previous discrimination task, and a mid-point was fixed at the outset of the Category Boundary task. This latter point cannot be determined in this experiment since the Category Boundary task always followed the discrimination task. Subsequent research will need to be done to determine whether this possibility can be eliminated.

Since both partial agreement and partial disagreement are found for both SCE models, it seems equally plausible that the two models of SCE may also be attempting to explain different aspects of human cognition involved in decision-making. Until the conflicting findings presented here can be reconciled (assuming replication), neither model in its current state can be postulated as a general theory of the perception of the aging process. Rather, each may be examined as a potential theory of the perception of a specific aging process.

Subsequent work is directed to replicate the above findings, to test the hypotheses with different psychophysical tasks, to investigate the representation of a scale for age using multidimensional techniques, and to examine individual differences in the POI and its relationship to alternative

indices of psychological age--both subjective and objective.

References

- Ager, J.W., & Dawes, R.M. (1965). The effect of judges' attitudes on judgment. Journal of Personality and Social Psychology, 1(5), 533-538.
- Audley, R.J. & Wallis, C.P. (1964). Response instructions and the speed of relative judgements. I. Some experiments on brightness discrimination. British Journal of Psychology, 55, 59-73.
- Banks, W.P. (1977). Encoding and processing of symbolic information in comparative judgments. In G.A. Bowes (Ed.), The Psychology of Learning and Motivation, Vol. 2. NY: Academic Press.
- Banks, W.P., Clark, H.H., & Lucy, P. (1975). The locus of the semantic congruity effect in comparative judgments. Journal of Experimental Psychology: Human Perception and Performance, 101(1), 35-47.
- Banks, W.P., & Flora, J. (1977). Semantic and perceptual processes in symbolic comparisons. Journal of Experimental Psychology: Human Perception and Performance, 3(2), 278-290.
- Banks, W.P., Mermelstein, R., & Yu, H.K. (1982). Discriminations among perceptual and symbolic stimuli. Memory & Cognition, 10, 265-278.
- Barak, B. (1987). Cognitive age: A new multidimensional approach to measuring age identity. International Journal of Aging

and Human Development, 25(2), 109-128.

Baranski, J.V., & Petrusic, W.M. (1991). Semantic congruity and the microstructure of the comparison process. Manuscript in preparation.

Baranski, J.V., & Petrusic, W.M. (1992). Comparative judgments with and without explicit reference points. Manuscript in preparation.

Birren, J.E., & Bengtson, V.L. (Eds.). (1988). Emergent Theories of Aging. New York: Springer Publishing Co.

Brown, F.G. (1983). Principles of Educational and Psychological Testing, 3rd edition. NY: CBS Publishing.

Clark, H.H. (1969). Linguistic process in deductive reasoning. Psychological Review, 76(4), 387-404.

Corso, J.F. (1981). Aging Sensory Systems and Perception. NY: Praeger.

Ellis, S.H. (1972). Interaction of encoding and retrieval in relative age judgments: An extension of the "crossover" effect. Journal of Experimental Psychology, 94(3), 291-294.

Fozard, J.L., Metter, E.J., & Brant, L.J. (1990). Next steps in describing aging and disease in longitudinal studies. Journal of Gerontology: Psychological Sciences, 45(4), P116-P127.

Holyoak, K.J. (1978). Comparative judgments with numerical reference points. Cognitive Psychology, 10, 203-243.

- Jamieson, D.G., & Petrusic, W.M. (1975). Relational judgments with remembered stimuli. Perception & Psychophysics, 18, 373-378.
- Marschark, M. & Paivio, A. (1981). Congruity and the perceptual comparison task. Journal of Experimental Psychology: Human Perception & Performance, 7, 290-308.
- Miller, G.A. (1956). The magical number seven, plus or minus two: Some limits on our capacity for processing information. Psychological Review, 63, 81-97.
- Pachella, R.G. (1974). The interpretation of reaction time in information-processing research. In B.H. Kantowitz (Ed.), Human Information Processing: Tutorials in Performance and Cognition, pp. 41-82. Hillsdale, NJ: Lawrence Erlbaum.
- Pedhazur, E.J. (1982). Multiple Regression in Behavioral Research, 2nd ed. NY: CBS College Publishing.
- Petrusic, W.M. (1991). Semantic congruity effects and theories of the comparison process. Journal of Experimental Psychology: Human Perception and Performance. In press.
- Petrusic, W.M., & Baranski, J.V. (1989). Semantic congruity effects in perceptual comparisons. Perception & Psychophysics, 45(4), 439-452.
- Petrusic, W.M., & Baranski, J.V. (1992). On the internal psychophysics: Binary and quaternary relational judgments with remembered and perceived magnitudes. Journal of Experimental Psychology: Learning, Memory & Cognition.

Under review.

- Posner, J. (1977). Old and female: The double whammy. In Essence, 2(1), 41-48.
- Salthouse, T.A. (1985). A Theory of Cognitive Aging. Amsterdam: North Holland.
- Schaie, J.E. (1972). Age changes and age differences. In W. R. Looft (Ed.), Developmental Psychology: A Book of Readings, 60-67. Hinsdale, Ill.: Dryden Press.
- Schonfield, D. (1989). Conflicting conclusions, gerontological theories and applications. Canadian Psychology, 30 (3), 507-515.
- Schroots, J.J.F., & Birren, J.E. (1990). Concepts of time and aging in science. In J.E. Birren & K.W. Schaie (Eds.), Handbook of the Psychology of Aging. San Diego: Academic Press.
- Shipley, W.C., Coffin, J.I., & Hadsell, K.C. (1945). Reaction time in judgment of colour preference. Journal of Experimental Psychology, 35, 206-215.
- Shipley, W.C., Norris, E.D., & Roberts, M.L. (1946). The effect of changed polarity of set on decision time of affective judgments. Journal of Experimental Psychology, 36, 237-243.
- Sternberg, S. (1975). Memory scanning: New findings and current controversies. Quarterly Journal of Experimental Psychology, 27, 1-32.

- Tabachnick, B.G., & Fidell, L.S. (1989). Using Multivariate Statistics, 2nd ed. NY: Harper & Row.
- Taylor, L.B. (1969). Localization of cerebral lesion by psychological testing. Clinical Neurosurgery, 16, 269-287.
- Tombaugh, T.N. (1989). An itemized scoring system for the Taylor Complex Figure. Unpublished Research, Carleton University.
- Tombaugh, T.N., & Faulkner, P. (1990). The relationship between subjective and objective measures of memory across a 60-year age span. Manuscript submitted for publication.
- Turner, J.S., & Helms, D.B. (1982). Contemporary Adulthood, 2nd. ed. NY: Holt, Rinehart & Winston.
- Wallis, C.P., & Audley, R.J. (1964). Response instructions and the speed of relative judgements. II. Pitch discrimination. British Journal of Psychology, 55, 121-132.

Appendix 1.

Stimulus faces used in both the discrimination and binary category tasks.

YOUNGER?

OLDER?

Appendix 2.

Taylor Complex Figure.

TOP

Appendix 3.

Summarized Scoring System for the Taylor Complex Figure
(Tombaugh, 1990).

Component	1 point	1 point	1 point
1. Large central square	3 sides completed	4 sides completed	sides equal length
2. Center horizontal line	left side	right side	touches middle both sides
3. Center vertical line	top side	bottom side	touches middle top & bott
4. Arrow (left)	vertical line, outside left	smaller than large square	arrowhead on top
5. Triangle (left)	figure, outside left	triangle	legs touch corners of squ
6. Horizontal line (triangle)	line inside triangle	horizontal line	joins base to apex
7. Horizontal line (upper)	top left square	top right square	touches middle both sides
8. Diagonal line #1 (top left)	begins upper left corner	begins lower right corner	diagonal line crosses cen
9. Diagonal line #2 (top left)	begins lower left corner	begins upper right corner	diagonal line crosses cen
10. Small square	small 4-sided figure(s) somewhere	all sides equal	single square, top left
11. Circle	small circle(s) somewhere	single circle, top left square	inside but not touching sq

Appendix 3 (Cont'd).

Component	1 point	1 point	1 point
Rectangle	4-sided figure above square	sides continuation of top left square	rectangle
Diagonal (top right)	begins lower left corner	begins upper right corner (no arrow)	diagonal line crosses center
Arrow (top right)	line outside, top right	touches upper right corner	arrowhead present
Semicircle	figure outside, right	touches middle of top & bottom square	semicircle
Triangle (inside)	figure, right half of square	touches middle of top & bottom square	triangle, apex at middle of sq
Vertical line inside triangle	line(s) inside triangle	single vertical line	touches middle of legs
Diagonal dots	diagonal line of dots	6-8 dots	exactly 7 dots
Horizontal line (bottom)	lower right	touches both sides	between lower 2 dots
Triangle (bottom)	figure outside, lower right	triangle	apex touches corner
Curved line	curved line, lower left	corner to corner	two peaks and a valley
Parallel lines	short diagonal lines, lower left	diagonal lines cross curved line	cross at peaks and valley
Star	star somewhere	below valley	8 points (4 intersecting lines)

Figure Caption

Figure 1. Predicted interaction between response category and relative stimulus values on a discrimination task.

Figure Caption

Figure 2. A Funnel Effect for brightness discriminations.

Figure Caption

Figure 3. Lexical Markedness Effect for age discriminations.

Figure Caption

Figure 4. Subjective and Experimental Reference Points on an Age Continuum.

a) Subjective Reference Points (I_o and I^o)

Stimulus Age range = 50 to 100

Bisector = 75

$$I_o = \beta I_s + (1 - \beta) \text{Min}_s$$

If $\beta = 0$, Min_s controls

If $\beta = 1$, I_o controls

b) Experiment Reference Points (Min_s and Max_s^*)

Stimulus Age range = 0 to 100

Bisector = 50

Figure Caption

Figure 5. Change in intercept (RT) due to physical slowing.

Figure Caption

Figure 6. Change in magnitude as a result of slowing mental processes or sampling rate.

Figure Caption

Figure 7. Mean response times at each level of Category Pairs for Age Group.

Figure Caption

Figure 8. Semantic Congruity Index (RT difference for each level of Category Pair) for each of the three Age Groups.

Figure Caption

Figure 9. Three-way interaction of Gender of the Subject, Category Pair, and Instruction using Mean RTs.

Figure Caption

Figure 10. Mean comparative judgement response times as a function of Block for Gender of the Face in the Photograph.

Figure Caption

Figure 11. Percent "error" at each Age Category Pair for each Age Group.

Figure Caption

Figure 12. Mean binary categorization response times at each Age Category for each Age Group.

Figure Caption

Figure 13. Psychometric functions for the binary categorization task for the three Age Groups.

END

22.1 2.92

FIN