UNIVERSITÉ DU QUÉBEC

MÉMOIRE PRÉSENTÉ À
L'UNIVERSITÉ DU QUÉBEC À TROIS-RIVIÈRES

COMME EXIGENCE PARTIELLE
DE LA MAÎTRISE EN PSYCHOLOGIE

PAR
SANDRA POULIOT

ANALYSE DU CARACTÈRE AUTOMATIQUE DE L'ENCODAGE ÉGOCENTRIQUE DE L'INFORMATION SPATIALE

SEPTEMBRE 2000

Ce document est rédigé sous la forme d'un article scientifique, tel qu'il est stipulé dans les règlements des études avancées (art. 16.4) de l'Université du Québec à Trois-Rivières. L'article a été rédigé selon les normes de publication d'une revue reconnue et approuvée par le Comité des études avancées en psychologie. Le nom du directeur de recherche pourrait donc apparaître comme coauteur de l'article soumis pour publication.

Sommaire

Parkin, Walter et Hunkin (1995) ont suggéré que l'encodage égocentrique de l'information spatiale est un processus cognitif automatique. Naveh-Benjamin (1987, 1988) a testé si l'information spatiale était encodée automatiquement en mettant à l'épreuve chacun des critères d'automaticité proposés par Hasher et Zacks (1979). Ses résultats ont montré que l'encodage d'informations spatiales ne s'effectue pas automatiquement. Cependant, la tâche de mémoire qu'il a utilisée a probablement favorisé un encodage allocentrique de l'information spatiale. Le but de la présente étude est de tester l'hypothèse de Parkin et al. (1995) grâce à une tâche informatisée qui induit un encodage égocentrique de la position de 60 dessins présentés individuellement et aléatoirement. Cinq études ont été menées pour mettre à l'épreuve chacun des critères d'automaticité d'Hasher et Zacks (1979). Les effets de l'intention d'apprendre ont été mesurés en comparant la mémoire spatiale égocentrique de 20 participants qui ont intentionnellement appris la position des dessins à celle de 20 participants l'ayant appris de façon incidente. Pour tester les effets d'une division de l'attention, la mémoire spatiale égocentrique de 20 participants effectuant une tâche interférente lors de l'encodage a été comparée à celle de 20 participants réalisant l'encodage de l'information spatiale seulement. L'effet de l'âge a été évalué en comparant la mémoire spatiale égocentrique de 20 adultes âgés de 65 à 76 ans à celle de 20 jeunes adultes ayant entre 19 et 36 ans. L'effet de la pratique a été testé en demandant aux 20 jeunes adultes de l'expérience précédente d'effectuer la tâche de mémoire spatiale égocentrique une deuxième fois. Finalement, l'effet des différences individuelles a été mesuré en mettant en corrélation la performance de mémoire spatiale égocentrique des 100 jeunes adultes

ayant participé aux quatre expériences précédentes avec leur score obtenu à un test de raisonnement non-verbal. Les résultats montrent que le vieillissement et la division de l'attention diminuent le nombre de positions spatiales correctement rapportées. Cependant, l'intention de mémoriser, la pratique et les différences individuelles n'ont pas eu d'effet significatif sur le rendement mnésique. Ces résultats partagés révèlent que l'encodage égocentrique d'informations spatiales n'est pas un processus purement automatique. Nos résultats sont en accord avec l'idée voulant que les processus d'encodage se situent le long d'un continuum de ressources attentionnelles (Hasher & Zacks, 1979). À une extrémité du continuum les processus seraient totalement automatique alors qu'à l'autre ils seraient parfaitement contrôlés. Parce qu'aucun critère d'automaticité ne s'applique à l'encodage allocentrique (Naveh-Benjamin, 1987, 1988) et que dans la présente étude, trois des cinq critères d'Hasher et Zacks (1979) sont vérifiés, nous suggérons que l'encodage égocentrique est plus automatique que l'encodage allocentrique de l'information spatiale, sans toutefois se situer à cette extrémité du continuum.

Abstract

Parkin, Walter and Hunkin (1995) suggested that egocentric space is automatically encoded. Using the criteria defined by Hasher and Zacks (1979), Naveh-Benjamin (1987, 1988) demonstrated that spatial information encoding was not an automatic process. However the spatial memory task used by Naveh-Benjamin (1987,1988) most likely emphasized encoding of allocentric space. In the present study, we tested Parkin et al's (1995) hypothesis using a task that was specifically designed to assess encoding of egocentric space. Five studies analyzing the effects of intent of memorization, dual task interference, old age, practice and individual differences were carried out using a computerized egocentric spatial memory task. Results showed that old age and dual task interference impaired egocentric spatial memory. However intent of memorization, practice and individual differences did not influence memory for egocentric positions. The findings demonstrate that encoding of egocentric space is not a pure automatic process and therefore requires some cognitive effort.

Table des matières

Remerciements

Si j'avais dû payer pour la supervision que m'a offerte le Dr. Sylvain Gagnon, je serais totalement ruinée. En effet, il est impossible que je réussisse à assez le remercier pour son immense disponibilité, pour sa remarquable maîtrise du renforcement et pour ses exigences élevées qui m'ont toujours stimulées et données le désir de repousser mes limites et celles de la connaissance. Je désire également lui exprimer ma gratitude pour m'avoir accordée sa confiance, dès le début du baccalauréat, en me permettant de me joindre au Laboratoire de neuropsychologie expérimentale et comparée. La réalisation de ce projet de maîtrise aurait été impossible sans la coopération et le soutien de tous les membres du laboratoire. Je tiens particulièrement à remercier Denys Kane, Isabelle Tremblay et Kathleen Soulard. Finalement, je dois mentionner que l'accomplissement de ce projet a été grandement facilitée par l'octroi d'une bourse d'étude du Conseil de Recherche en Sciences Naturelles et Génie du Canada.

Introduction

Remembering spatial information (location of objects in space) is indispensable for a functional everyday life. Indeed, successful adaptation requires that we must remember several types of spatial information such as where we have parked our car, where we have let the last version of an important writing or the location of the pay department at our new job, etc. There is no shortage of spatial information that is crucial to memorize. Because of its central importance to human and other species' cognition, the nature of space and how it is processed and remembered has prompted an impressive contingent of empirical studies and theoretical proposals (see Schacter & Nadel, 1991; Uttl & Graf, 1993).

In their seminal book, O'Keefe and Nadel (1978) suggested that space is processed in two different ways, that is, based on egocentric or allocentric parameters. To efficiently encode egocentric spatial information, the observer uses his/her body as a central axis around which objects are positioned (Abrahams, Pickering, Polkey & Morris, 1997). Allocentric encoding of an object is based on specific stimuli or landmarks that are independent from the subject's body orientation and position in space (Kesner, Farsnworth & DiMattia, 1989). In other words, allocentric encoding relies on the encoding of relations (distances, angles, geometric property) between the positions of diverse items and the position of the object to be remembered, independently from the encoder's spatial position. It allows the elaboration of a cognitive map (Benhamou, 1997; Tolman, 1948).

The resulting memory traces of the two types of spatial encoding are profoundly different. In an egocentric memory trace, the relationships between the spatial coordinates of the subject's body position and the spatial coordinates of the object's position are encoded (body-centered coding). Because egocentric encoding depends totally on the encoder's body position, if the encoder's position changes significantly at the time of recall, egocentric cues are not sufficient to relocate the position of an object. In contrast, an allocentric memory trace does not necessarily include the coordinates of the subject's position (but see Save, Poucet, Foreman & Thinus-Blanc, 1998). This type of encoding allows the encoder to retrieve the object's location without necessarily being at the encoding location; as long the spatial coordinates are still perceptible (environment centered coding). Whether spatial information be egocentric or allocentric, its essence remains the same: it is a position in space. However a recent study by Woodin and Allport (1998) provides clear evidence of a functional dissociation between the two types of spatial coding in adults. In their experiment, subjects with theirs eyes closed were seated and had to remember the location of target sounds presented around them. After the target presentation, the chair was smoothly rotated and an allocentric or egocentric interference task was introduced. Subjects were then asked to recall the target location either "as if it has moved with you" (body-centered condition) or "as if the location has not moved with you" (environment-centered condition). In the body-centered condition, the performance was significantly reduced by the egocentric interference task. In the environment-centered condition, the inverse pattern of results was observed. The allocentric interference task was the only one to impair the performance. This finding demonstrates the existence of a functional double-dissociation between egocentric and allocentric spatial coding.

The distinction between egocentric and allocentric encoding also rests on neuroanatomical and developmental dissociations. There are evidences suggesting that egocentric and allocentric information are processed by different parts of the brain. For instance, individuals suffering from a frontal lobe lesion expressed difficulty executing a task where they must rely on egocentric spatial information (road map test), but experienced no difficulty to copy a bidimensional scheme (Butters, Soeldner & Fedio, 1972, have considered this task to be allocentric). When the same tasks were administered to patients with parietal lobe lesion, the reverse pattern of results was observed. They showed impaired performance only on the allocentric task (Butters et al., 1972). In addition, a Kesner et al.'s (1989) study in rats also confirmed a double-dissociation of the functions of prefrontal and parietal cortices in processing of egocentric and allocentric information. Recent studies (Holdstock, Mayes, Cezayirli, Aggleton & Roberts, 1999; Holdstock, Mayes, Cezayirli, Isaac, Aggleton & Roberts, 2000) have also showed that the medial temporal lobe is necessary for allocentric but not egocentric spatial memory tasks.

On a different note, recent evidence suggests a probable developmental dissociation. These observations originates mainly from the cognitive aging literature. In fact, older adults' capacity to encode spatial information is the source of a persisting debate. This polemic takes roots in the results of studies that revealed a significant age related spatial memory deficit (Cherry & Park, 1989; Zelinski & Light, 1988) and on those studies that did not reveal such a decline (McCormack, 1982; Ozekes & Gilleard, 1989). Interestingly, the studies at the center of this controversy did not consider the double nature of spatial information and for that matter do fit within the egocentric-allocentric dissociation.

In fact, a closer analysis of the tasks used to assess spatial memory in those studies is extremely revealing. When allocentric encoding of spatial information appears to be the most efficient way to encode positions of objects (for example, subjects have to remember the locations of blocks in a three-dimensional matrix or the positions of 20 objects placed on a 6X6 matrix) (Cherry & Park, 1989, 1993; Naveh-Benjamin, 1987, 1988) significant age-related declines are reported. On the other hand, experiments requesting egocentric encoding of spatial information (for example, subjects have to remember the position of items presented on their left or on their right, or on the upper or lower part of a sheet of paper) did not observe age-related differences (Ellis, Katz & Williams, 1987; McCormack, 1982; Ozekes & Gileard, 1989; Parkin, Walter & Hunkin, 1995; but see Park, Puglisi & Lutz, 1982; Park, Puglisi & Sovacool, 1983). In a recent study that was specifically designed to examine the effect of aging on memory for egocentric and allocentric spatial information, Desrocher and Smith (1998) showed that old age impaired memory for allocentric spatial information but did not impair memory for egocentric spatial information. Moreover, animal studies of cognitive aging have showed that in rats, allocentric encoding becomes less efficient in old animals (Kikushui, Tonohiro & Kaneko, 1999). Interestingly, when spatial information is encoded egocentrically, the performance of old rats and younger rats is rather similar (Barnes, Nadel & Honig, 1980; Gage, Dunnet & Bjorklund, 1984; Gagnon, Winocur & DiFrancesco, 1996; Gallagher & Burwell, 1989; Van der Stayy & De Jong, 1993).

The question that arises from the previous observations is why older adults experience difficulty remembering allocentric information while showing intact performance on egocentric tasks? One interesting interpretation imputes this dissociation to the differential cognitive demands (attentional resources) of egocentric and allocentric encoding of spatial information. According to Craik, Byrd and Swanson (1987), most age-related cognitive impairments are a manifestation of a reduction in processing resources (or attentional resources). Consequently, complex, novel or effortful tasks requiring substantial resources should show age-related differences whereas simple or automatic cognitive operations should be realized easily because little cognitive resource (or not at all) is needed (Craik and Anderson, 1999).

Hasher and Zacks (1979) have proposed that encoding of spatial information (with no consideration of the type) is performed automatically, that is, draining minimal energy from attentional capacity. They also proposed that behavior resulting from an automatic process should not be influenced by old age, the intention to learn (intentional or incidental learning), the division of attention, practice and individual differences (such as motivation, intelligence and academic education). Consequently, processing and remembering spatial information should not be influenced by any of these factors.

In an interesting series of four experiments, Naveh-Benjamin (1987, 1988) tested whether the five automaticity criteria proposed by Hasher and Zacks (1979) apply to spatial memory. In his study, participants were asked to memorize the position of 20 little drawings randomly placed on one of 36 squares of a checkerboard made of 6 rows and columns. In the first study, the effects of age and intention to learn were manipulated by asking young and old participants to perform an orienting task. Only half of the participants from both age groups were warned that their memory of the object positions would be assessed. In the second study, the effect of division of attention was measured by comparing the performance of participants executing a difficult interfering task (count backwards by 13s) while studying the drawings' positions to the performance of participants who were only requested to study the drawings' positions and to count backwards by 1s. In a third experiment, the learning effect was evaluated by asking the participants to perform the task twice. Finally, to measure the influence of individual differences, spatial memory of university students admitted in a department using highly selective standards was compared to the performance of participants studying in a department where admission standards were more liberal. In all four experiments, the results confirmed that spatial memory processes do not operate automatically. It was found that spatial memory scores were significantly affected by each automaticity criterion.

The observations made by Naveh-Benjamin (1988) are difficult to challenge. However, he did not consider the double nature of spatial information. We believe that the method he used favored allocentric encoding over egocentric encoding. This methodological limitation is extremely relevant since Parkin et al. (1995) have proposed that encoding of egocentric spatial information operates automatically, as described by Hasher and Zacks (1979), whereas allocentric encoding is considered as an effortful process. According to them, age differences were scarcely observed in tasks emphasizing egocentric encoding because this type of encoding does not require cognitive resources.

However a few studies, where egocentric encoding of the spatial positions was needed, have showed significant age-related differences (Park et al. 1982; Park et al.1983). Already, the results are not univocal as long as the sensitivity to old age is considered. These observations suggest that egocentric encoding of spatial information might not be a straightforward automatic process as proposed by Parkin et al. (1995). At this stage, we believe that it is extremely relevant to evaluate whether egocentric spatial information is processed automatically or not. In order to achieve this goal, the five automaticity criteria (Hasher & Zacks, 1979) were applied to a spatial memory task that emphasized encoding of egocentric coordinates. The task selected also prevents encoding of allocentric coordinates.

Because some studies have shown that egocentric encoding declines with age, we hypothesized that encoding of egocentric spatial information does not consist in a fully automatic process and therefore requires some attentional resources. Accordingly, we expect that some of the manipulations designed to test each automaticity criterion should significantly influence the number of spatial positions correctly recalled.

Experiment 1

In this experiment, memory of egocentric spatial information was tested following incidental or intentional learning.

Method

Participants

Forty young adults (20 women, 20 men) participated voluntarily in this study. All participants were French-speaking undergraduate students from Université du Québec à Trois-Rivières. They ranged in age from 19 to 34 years (M= 22.5, SD=3.89). Participants from each experiment (1 to 4) described themselves as healthy at the time of testing. Individuals with major health problems, neuropsychological, psychiatric or alcoholism antecedents were excluded.

Material

Neuropsychological tests. The vocabulary sub-test from the Épreuve Individuelle d'Habileté Mentale (EIHM, Chevrier, 1989, ["Individual test of mental abilities", free translation]) was administered. This sub-test is made of 42 words presented in an order of increasing difficulty. This test provided an estimate of the depth of verbal knowledge (Braun, 1997).

The short form of Raven's Progressive Matrices (Neuropsychological Laboratory, 1979) was also used. This form is made up of 30 out of the 60 original progressive matrices. The matrices were bound together in a 22 X 28 cm booklet, with one problem appearing on each page. This test assesses non-verbal reasoning capabilities.

Spatial memory. The spatial memory task was programmed using Visual Basic 6.0 (Microsoft). Using a Seanix computer (Pentium II, 233 MMX), stimuli were presented on one of two monitors (Seanix 47,5 cm). The monitors were placed 75 cm apart (center to center) on a 75 cm high table.

In a preliminary study, 200 drawings selected from a large pool of images included in a commercial software package (Corel Draw) were presented to 20 naive volunteers (18-35 years old). They were asked to rate, on a five point Likert scale, how familiar and recognizable the depicted objects were. One hundred and twenty three drawings rated as highly familiar and recognizable (at least 4/5 on each scale) were retained. From those, two experimental sets of 60 drawings and one practice set of three, were created. All drawings depicted objects belonging to various semantic categories (tools, furniture, toy, food, etc.), were brightly colored and measured approximately 10 cm by 10 cm. They were presented on a light gray background.

Procedure

Ten men and ten women were randomly assigned to one of two experimental conditions (intentional or incidental learning). Each participant was tested individually. After signing the consent form, the participant was invited to sit in a chair placed at 75 cm in front of the two computer monitors (see Figure 1). The participant was then encouraged to read the upcoming task's instructions appearing on the left monitor. The instructions let the participant believed that he was about to participate in an experiment designed to assess the effect of vigilance on processing speed of visual information. For each drawing that was presented, each participant had to quickly answer the following question: " Where can this object be found?". For example, if the presented drawing depicted a fish, one could answer: "in the sea", "in a fisherman's net" or even "on a table, in my favorite dish". Participants in the incidental learning condition were told to be particularly vigilant because they could never predict on which screen the next drawing was to appear. The presence of a microphone was also signaled to them. They were told that their answers were recorded to compute their reaction times. However, participants in the intentional learning condition were informed that a test measuring their memory of the drawings' positions would follow. Just before the encoding phase took place, the three drawings from the practice set were randomly presented to the participants so they could be familiarized with the orienting task.

Insert Figure 1 about here

Encoding. In each condition, half of the participants were randomly assigned to one of the two drawing sets. After reading the instructions and performing the practice trials, the participant pressed the space bar on the computer keyboard to begin the presentation of the drawings. The drawings were randomly presented on one monitor or the other. However, the following restrictions were respected: 1) thirty out of the 60 drawings appeared on each monitor, 2) the specific position of a drawing on the monitor varied randomly and 3) no more than three consecutive drawings were presented on the same monitor. Each drawing was presented for 3000 ms with an inter-stimuli interval of 1500 ms. During that interval, nothing appeared on the monitors. After the presentation of the 60 drawings, participants were distracted by a 3 min written subtraction task. This task was used to prevent active rehearsal strategies during the delay.

Retrieval. In this phase of the experiment, the monitor on the right hand side of the participant was shut down and the monitor on the left was moved in front of the participant (see Figure 1). Instructions for the spatial memory test were then given to the participants of both experimental conditions. The drawings were individually and randomly presented a second time, but only on the activated monitor now situated in front of the participant. Each drawing was presented in the center of the monitor, and under each one, the words left and right appeared inside a green rectangle. The participant indicated whether the drawing was originally presented on the left or the right hand side monitor by selecting one of those two words with the left or right arrow keys. The subject had to give one answer for each drawing, and when in doubt, guessing was encouraged. To proceed with the next drawing, participants were told to press the space bar. This procedure allowed self-paced retrieval of the spatial positions.

After this test, participants responded to a post-experimental questionnaire in which they rated the difficulty of the task and expressed whether or not they had been equally attentive to the drawings presented on the left and right hand side monitor. Participants in the incidental condition were also asked whether they knew that their memory would be later tested and consequently whether they tried or not to memorize the monitor on which the drawings appeared. The vocabulary sub-test and the Raven Progressives Matrices were administered after the spatial memory task.

Results and Discussion

A 2 (experimental condition) X 2 (drawings set) X 2 (gender) factorial analysis of variance was performed using the number of drawing positions correctly recalled as the dependant variable. The effect of gender was included in the analyses because a number of spatial memory studies have found this effect to be a significant factor (Jue, Meador, Zamrini, Allen et al., 1992; Masters, 1998; Postma, Izendoom & De Haan, 1998). The criterion of statistical significance was set at $\alpha \leq .05$ for all tests reported in this article. The maximum score that could be obtained was 60 (see Table1). The analysis showed that none of the three main factors were significant [$F(1,39)=0.85$, n. s., $F(1,39)=0.59$, n. s., $F(1,39)=2.36$, n. s., respectively]. In addition, no significant interaction between the three variables was observed (all p's $\geq .05$).

Insert Table1 about here

This analysis revealed that the participants in the incidental learning condition did not perform better or worse than the participants who were fully aware of the upcoming memory test. This absence of effect took place within a truly incidental task situation. Indeed, the participants from the incidental condition were never asked to remember any information, be it the spatial position, the drawings or their answers. Moreover, as reported during the post-experimental questionnaire, no participant from the incidental learning condition was aware or suspicious that a memory or spatial memory test would follow. Therefore, Hasher and Zacks' (1979) criterion specifying that an automatic process occurs equally well under incidental or intentional learning instructions can be applied to memory for egocentric spatial positions. It should also be noted that even if the number of elements to remember was important, spatial memory was impressive and participants from both experimental conditions reported that they recognized all drawings.

Experiment 2

In this study, we tested the claim that an automatic process shall not be disturbed by simultaneous processing demands. Half the participants were submitted to a dual task while encoding the egocentric spatial position of the drawings. In a preliminary study, the PASAT (Paced Auditory Serial Addition Task, Gronwall, 1977) using the slower presentation rate was administered at encoding time. Although the two tasks did not overlap in terms of sensory modality, all attentional resources of our participants seemed to be requested by the PASAT. As a result, the spatial memory performance was at chance level. Participants reported being unable to process any information about the drawings that were presented on the monitors. Then, we conceived a simple task with a stable difficulty level that allows the participants to attend all stimuli. In this task participants heard three syllables abstract words and had to repeat them, one at a time, while encoding the egocentric spatial positions.

Method

Participants

Forty young naive participants (20 women, 20 men) aged between 19 and 35 years ($\underline{M}$= 22.73, $\underline{SD}$=3.79), volunteered to participate in this experiment.

Material

In order to administer the interfering task, 135 abstract words were recorded on an audiotape. The chosen words had three syllables or more. One word was presented every two seconds. Apart from the interfering task, the material used for the spatial memory task was identical to Experiment 1.

Procedure

An equal number of men and women were randomly assigned to each condition (encoding under dual task or not). After taking place in front of the two computer screens, the instructions were given. The subjects were told that they had to learn on which side each drawing appeared. They were also informed that at the same time they would hear words. Participants from the division of attention condition were asked to repeat each word once while memorizing the egocentric position of the drawings. It was made clear to them that learning the drawings' positions was as equally important as repeating each word correctly. Participants from the other experimental condition were told to ignore those words. Right before the encoding phase, the drawings from the practice set were randomly presented and six recorded words were played, so the participants could be familiarized with their respective task. Immediately after, the three drawings were once again presented but only on the left side monitor so the participants got acquainted with the recall procedure. All other procedural aspects were identical to Experiment 1.

Results and Discussion

The results of each group are presented in Table 1. A 2 (experimental condition) X 2 (drawing set) X 2 (gender) factorial analysis of variance was conducted on the number of correctly recalled positions. The implementation of a dual task at encoding appears to lead to an impoverished performance. The experimental condition factor was the only significant effect [$F(1,40)=6.27$, $p<.05$]. All other main effects, as well as the interactions, did not reach significance. These results do not support the hypothesis that egocentric spatial encoding is an automatic process.

Even though the dual task used in this experiment seemed at first sight fairly easy, most subjects (16 out of 20) reported that the task prevented them to properly memorize the drawings' position. This dual task was designed to tax a different sensorial modality than the one monopolized by the spatial memory task, but nonetheless it interfered with egocentric encoding of spatial information.

Experiment 3

In this experiment, the effect of old age on memory for egocentric spatial information was examined. The recall performance of a group of young adults was compared to the one of a group of elderly people.

Method

Participants

The young adults group was made up of 20 undergraduate students (10 women, 10 men) aged between 19 and 36 years (M= 22.15, SD= 3.86). The elderly group consisted of twenty older adults (10 women, 10 men) aged between 65 and 76 years old (M=69, SD=3.35). They were recruited through a local newspaper advertisement. They were all autonomous and community dwelling. None of the aged persons showed indication of significant cognitive functions alteration as measured by the Mini Mental State (MMS) (Folstein, Folstein & McHugh, 1975).

Material

The Mini Mental State examination was administered to the older participants. The remaining material was identical to Experiment 1.

Procedure

The procedure was similar to the previous experiments. Participants practiced encoding and recall. In order to avoid keyboard manipulation mistakes from the older adults due to a lack of familiarity, the experimenter pressed in their answers (during practice and experimental trials). After the memory test, all participants answered a post-experimental questionnaire and the vocabulary sub-test was administered. Furthermore, young participants completed the Raven Progressives Matrices (short form) whereas the MMS was administered to older adults.

Results and Discussion

The young participants had more formal years of education (M=14.75, SD=2.15) than the older ones (M=11.25, SD=3.37) [t(38)=3.92 p<.05]. However, years of education were not related to the egocentric spatial memory performance [r(38)=-0.077 n.s.] and for that reason was not statistically considered. There was no difference between the vocabulary scores of young adults (M= 51.75) and aged participants (M= 47.15) [t=(38)=0.0114 n.s.]. We consider this result as evidence that apart from the age factor, the two groups were relatively equivalent.

Because no drawing effect or gender differences were found in Experiments 1 and 2, these factors were no longer included in the following statistical analyses. A t-test with age groups as the independent variable was conducted on the number of correct positions recalled. It revealed that young subjects showed better memory performances than older participants [$t(38)=2.66$ $p<.05$] (see Table 1). As it was observed by Naveh-Benjamin (1987, 1988) in a spatial memory task that emphasized allocentric encoding, the results of this experiment do not support Hasher and Zacks' (1979) assumption that old age has a minimal impact on spatial memory. Our findings clearly demonstrate that memory for egocentric positions declines with old age.

Experiment 4

This experiment was concerned with the effect of practice on memory for egocentric spatial information. In order to assess this effect, a group of young subjects performed the task a second time. Egocentric spatial memory performance on the first trial was compared to participants' performance on the second trial.

Method

Participants

Young participants of Experiment 3 (first trial).

Material

The material was identical to the preceding experiments.

Procedure

After executing the task a first time (in Experiment 3), all participants performed the spatial task a second time. However, they studied a new set of drawings to prevent proactive interference. Other procedural aspects were identical.

Results and Discussion

In this experiment, the number of correct positions recalled was computed for the first and second test trial (see Table 1). Performance did not seem to improve from the first to the second trial. A t-test with trial order as the independent variable was conducted on the mean number of correct positions recalled. The analysis revealed that the differences observed between the two test trials did not reach significance [$t(38)=0.26$, n. s.].

Because participants in the practice condition had only one prior experience with the task and that no learning strategy were suggested to them on the second trial, it can be argued that the practice manipulation included in this study was not effective. However, using the same manipulation, Naveh-Benjamin (1987, 1988) observed a significant effect. Moreover, it can be pointed out that even if we wanted to prevent proactive interference by presenting a different but similar drawing set on the second trial, proactive interference could have nonetheless occurred and prevented the observation of an eventual learning effect. However, this possibility appears quite unlikely because the second trial took place about half an hour after the first one, and no participant reported confusing the two drawing sets.

The results of this experiment are consistent with the criterion which states that practice does not improve the efficiency of an automatic operation (Hasher & Zacks, 1979).

Experiment 5

To evaluate the effect of individual intellectual differences on an automatic process, we favored a correlational method. Egocentric spatial memory was related to a non-verbal reasoning test (Raven Progressive Matrices [short form]).

Method

Participants, Material and Procedure

The number of drawings' position correctly recalled by the 120 participants included in the four preceding experiments was correlated with their vocabulary score. Spatial memory results of the 100 young adults who participated in Experiments 1, 2 and 3 were correlated to their score on the Raven Progressive Matrices.

Results and Discussion

No correlation was found between the number of positions correctly recalled by the young adults and their scores on the Raven Progressive Matrices [$r(99)=0.06$, n. s.]. Similarly, no correlation was noticed between the egocentric spatial memory score and the vocabulary score [$r(119)=0.05$, n. s.]. These results suggest that individual intellectual differences have no effect on egocentric spatial memory.

General Discussion

As predicted, the present findings do not support the idea that spatial egocentric information is processed automatically. Some of Hasher and Zacks' (1979) automaticity criteria were supported while others were not.

We observed that under division of attention, young adults' egocentric spatial memory decreased significantly. Our results also revealed that young adults achieved significantly higher memory performances in comparison to older adults.

However, three findings are consistent with Parkin et al.'s (1995) proposal that egocentric encoding of spatial information is processed automatically. Participants who learned the egocentric information incidentally performed as well as participants who learned the same information under intentional instructions. Moreover, our results showed that previous practice with the task did not enhance performance on a subsequent trial. Finally, the results of the last experiment revealed that individual differences had no significant influence on egocentric spatial memory.

The framework proposed by Hasher and Zacks (1979) specifies that encoding processes could be situated along a continuum of attentional demands; processes at either end of this continuum are considered fully automatic or very effortful. Consequently, if all of Hasher and Zacks (1979) criteria of automaticity have to be supported for a cognitive process to be considered automatic, the results of the present study clearly show that egocentric encoding of spatial information does not correspond to a perfectly automatic process. Nevertheless, egocentric encoding appears to require less effort than allocentric encoding. As mentioned earlier, Naveh-Benjamin (1987,1988) demonstrated in two different studies on spatial memory using tasks that most likely emphasized allocentric encoding, that this type of spatial information was sensitive to each one of the five automacity criteria. The suggestion that one type of spatial encoding is more automatic than another one might appear to fit nicely within Hasher and Zacks' (1979) framework. However, we make a clear distinction between two types of spatial encoding which departs from Hasher and Zacks' initial view that spatial information, regardless of its nature, ought to be processed automatically. In addition, our findings do not support entirely the suggestion made by Parkin et al. (1995) which states that egocentric information is processed automatically. As we just described, processing of egocentric information does require some attentional effort.

In order to reach a better understanding of how egocentric information is processed, we first need to examine why some automaticity criteria were supported while others were not. Because of the existence of conflicting results in the literature, we expected that some criteria would influence egocentric spatial memory. One of these criteria is the effect of old age. The present results corroborate findings of numerous studies that showed the adverse effect of aging on spatial memory, be it allocentric (Cherry & Park, 1989; Naveh-Benjamin, 1987, 1988) or egocentric (Park et al., 1982; Park et al., 1983). In contrast, the present data offer no support to Desrochers and Smith's (1998) findings suggesting that egocentric spatial memory does not decline with age. Desrochers and Smith's (1998) study was designed to compare egocentric and allocentric spatial memory in older adults using the same number of stimuli in both conditions. Unfortunately, because of two major methodological limitations, their results do not seem tenable. First of all, the nature of spatial encoding was not controlled. Indeed, in either condition, the encoding instructions were exactly the same. Consequently, participants were free to use egocentric, allocentric or any other encoding strategy. It seems counter-intuitive to believe that the manipulation they introduced at retrieval (retrieval based on egocentric or allocentric cues) influenced how the objects' position were encoded. Secondly, the participants tested in the allocentric condition had to relocate twice the number of items in comparison to participants in the egocentric condition. Therefore, one should have predicted larger differences in the allocentric condition. Moreover, in a study where allocentric and egocentric encoding was controlled and where the number of stimuli was equivalent in both encoding and recall conditions, allocentric and egocentric spatial memory deficits were found in elderly participants in comparison to young adults (Boucher, 1999).

The effect of old age on both egocentric and allocentric encoding could be reduced to a simple explanation. As highlighted by Andrade and Meudel (1993), in order to efficiently recall the position of an object, one not only has to remember the particular object and a specific position in space, but also has to bind together those central features in order to associate objects to specific locations. Indeed, some researchers have found a dissociation between these two processes (Chalfonte & Johnson, 1996; Mayes, Meudell & Macdonald, 1991; Postma & DeHaan, 1996).

Chalfonte and Johnson (1996) observed that older adults not only have a memory deficit for spatial information but also show impaired memory for complex events that are combinations of any information. It is proposed that older adults have a difficulty uniting various informations into a single event. Chalfonte and Johnson (1996) expressed the idea that the age-related binding deficit is caused by a reactivation failure. The reactivation process brings back information to a more active state, and allows an internally generated repetition of that information. Reactivation increases binding opportunities and strengthens existing relations. This reactivation deficit proposal is germane to Craik's (1986) reduced resources hypothesis. This hypothesis states that older adults' performance will be disproportionately low when retrieval of the encoded information requires self-initiated (or internally generated) operations. Consequently, when a memory task necessitates binding of information, age-related deficits ought to be observed based on the hypothesis of reduced resources. If this interpretation is true, it is yet impossible to determine whether one type of encoding declines more than the other with old age because all spatial memory tasks require the involvement of a binding process. In fact, in all spatial memory tasks, several objects are presented during the encoding phase, a procedure that increases the binding effort. Other studies are therefore needed to disentangle spatial (egocentric or allocentric) memory deficits from binding deficits in older adults.

One important prediction of the reduced resources hypothesis is that the performance of young adults should be reduced to the level of elderly adults' performance when conditions lessen their attentional resources. We observed that simultaneous processing demands resulted in a poorer memory performance in young adults, a performance highly similar to the one of elderly participants (see Table 1). However, our procedure does not allow us to determine what process was impaired by the presence of a dual task. In their study, Andrade and Meudell (1993) found that division of attention impaired item memory but had no effect on memory for space. Unfortunately, in our experiment, drawing recognition was not tested independently from the spatial memory. Therefore, it is impossible to infer whether the interfering task influenced drawing memory as observed by Andrade and Meudell (1993) or egocentric encoding or both. However, since our participants reported recognizing all drawings in the post-experimental questionnaire, Andrade and Meudell's (1993) findings might not apply here.

There is another potential interpretation of the division of attention results. One could suggest that egocentric encoding of spatial information was subserved by verbal cues. In fact, half of the participants who intentionally encoded the egocentric positions reported using verbal strategies in the post-experimental questionnaire. For example, when encoding a drawing (e.g. a policeman) showed on the right monitor, a participant could mentally rehearse something like "policeman is on the right". Some participants also reported using deeper verbal associations (25% in intentional conditions). For example, one could associate the right side with something good and the left side with something bad. To remember that the policeman was presented on the right monitor, a participant could elaborate something like: "policemen are good". In the single task condition, participants were free to use the strategy (verbal, egocentric or else) of their choice. Conversely, the division of attention condition might have induced articulatory suppression and prevented participants from using verbal strategies. This interpretation is in line with Postma and De Haan's (1996) results that revealed that the assignment of an object to a specific position in space deteriorates with articulatory suppression. Nevertheless, our results clearly demonstrate that the process of assigning an object to a position in space requires attentional resources.

Some of Hasher and Zacks' (1979) criteria of automaticity did not influence egocentric spatial memory. These three criteria provide some support to Parkin et al.'s (1995) proposition that egocentric space is automatically encoded. However, because alternative explanations are possible, this support has to be considered with caution.

In the present study, intention to learn or awareness that a memory test would follow the orienting task did not influence spatial memory. The most simple explanation for this robust finding is that processing of spatial egocentric information does not require attentional resources. However, in Naveh-Benjamin's (1987, 1988) studies, a reduced performance in the incidental condition was observed, a result which could originate from his orienting task. During encoding, participants rated the everyday usefulness of the depicted objects. This task did not orient the participant's attention towards any spatial meaning that could be associated with the object depicted on the drawing. In contrast, in the present study, participants had to name a place where they could find the object. The impressive performance we obtained in our incidental learning condition could originate from the spatial nature of the orienting task. Without explicitly asking the participants to memorize the objects or their spatial positions, the processes necessary to execute this task may have induced incidental encoding of spatial parameters. Indeed, participants were forced to activate a mental representation that associated the object with a spatial location. This alternative explanation, although quite speculative at this point, deserves further empirical investigation.

The second automaticity criterion that did not influence egocentric spatial memory is the effect of practice. Egocentric spatial memory did not improve after participants were given a second test. Although this result supports the notion that egocentric encoding is an automatic process, the validity of this criterion could also be questioned. First of all, the performance was very high right on the first trial and the chance to observe improvement on a subsequent trial was limited. However, such a result had to be expected if the processes involved were activated automatically. Consequently, performances on automatic tasks should be high right from the very start and any improvement will be difficult to see or will not even happen. In other words, this criterion could only be valid under specific circumstances, that is, when performance on the initial trial is rather low. In such a situation, improvement on subsequent trials should be interpreted as an increase due to learning of strategies or development of automaticity.

Finally, results on the memory task did not vary according to individual intellectual differences. Indeed, no significant relationship was found between egocentric spatial memory scores and a measure of non-verbal reasoning (Raven Progressive Matrices). Here again, alternative explanations can account for the lack of variation caused by individual differences. Our spatial egocentric memory task emphasizes episodic memory and spatial processing, which differs substantially from the Raven's Progressive Matrices. This test assesses non-verbal reasoning capabilities whereas our egocentric task emphasizes processing of parameters necessary to establish the position of objects in space. Finally, the failure to observe a significant statistical relationship could also be attributed to the lack of variability in the memory scores. To be powerful, the correlational approach requires a better evaluation of individual differences. In the present study, we only considered a small fragment of individual differences by concentrating on non-verbal reasoning. However, we should also mention the egocentric spatial memory scores did not correlate with a measure of verbal knowledge (Vocabulary scores), $r(119)=.05$ n.s.

On a different note, one could argue that the findings of Naveh-Benjamin and the present pattern of results are related more to the difficulty of the respective spatial memory tasks than to their egocentric or allocentric nature. However, a closer look at the results reveals that the global difficulty levels are quite comparable. Indeed, in Naveh-Benjamin's (1988) study, participants in the intentional learning condition correctly recognized 82% of the spatial locations whereas 86% of the spatial location were correctly recalled in the present study. Moreover, in Naveh-Benjamin's (1988) task, participants had to memorize 20 objects and could allocate 4,5 seconds to the encoding of each object. In comparison, in the present experiment, participants had to learn the positions of 60 drawings and 3 seconds was allowed to study each drawing. These considerations are convincing evidences that the difficulty of the task cannot explain the disparity between Naveh-Benjamin's (1988) results and ours. However, this resemblance between global memory performances was only achieved by multiplying the number of targets to be remembered by three. We believe that this is a demonstration that encoding allocentric spatial information requires a greater amount of attentional resources. Nevertheless, the level of difficulty appears as a very important issue that deserves further attention. In further experiment, it would be relevant to manipulate the difficulty level of an egocentric task (e.g.: to have more than 2 possible egocentric spatial locations) in order to evaluate whether the task's sensitivity to automaticity criteria increases or not.

In conclusion, Parkin et al's (1995) hypothesis that egocentric encoding is an automatic process is partly supported. Because two of the criteria proposed by Hasher and Zacks' (1979) were not met, egocentric encoding cannot be considered as a pure automatic process. However, egocentric encoding appears to be more automatic than allocentric encoding based on Naveh-Benjamin's results.

References

Abrahams, S., Pickering, A., Polkey, C. E., & Morris, R. G. M. (1997). Spatial memory deficits in patients with unilateral damage to the right hippocampal formation. *Neuropsychologia, 35(1),* 11-24.

Andrade, J., & Meudell, P. (1993). Is spatial information encoded automatically? *The Quarterly Journal of Experimental Psychology, 46A(2),* 365-375.

Barnes, C. A., Nadel, L. & Honig, W. K. (1980). Spatial memory deficit in senescent rats. *Canadian Journal of Psychology, 34,* 29-39.

Benhamou, S. (1997). On systems of reference involved in spatial memory. *Behavioral Processes, 40,* 149-163.

Boucher, G. (1999). *Déficience de la mémoire épisodique spatiale chez la personne âgée: étude des processus d'encodage*. Unpublished master thesis, Université du Québec à Trois-Rivières.

Braun, C. M. J. (1997). *Évaluation neuropsychologique*. Montreal: Décarie Éditeur.

Butters, N., Soeldner, C., & Fedio, P. (1972). Comparison of parietal and frontal lobe spatial deficits in man : Extrapersonal vs personal (egocentric) space. *Perceptual & Motor Skills, 34,* 27-34.

Chalfonte, B. L., & Johnson, M. K. (1996). Feature memory and binding in young and older adults. *Memory & Cognition, 24,* 403-416.

Cherry, K. E., & Park, D. C. (1989). Age-related differences in three-dimensional spatial memory. *Journals of Gerontology, 38,* 190-196.

Cherry, K. E., & Park, D. C. (1993). Individual differences and contextual variables influence spatial memory in younger and older adults. *Psychology and Aging, 8(4),* 517-526.

Chevrier, J. M. (1989). *Épreuve individuelle d'habileté mentale*. Montreal: Institut de Recherches Psychologiques, inc.

Craik, F. I. M. (1986). A functional account of age differences in memory. In F. Klix & H. Haggendorf (Eds.), *Human memory and cognitive capabilities* (pp. 409-422). Amsterdam : Elsevier/North-Holland.

Craik, F. I. M., & Anderson, N. D. (1999). Applying cognitive research to problems of aging. In D. Gopher, A. Koriat et al. (Eds.), *Attention and performance XVII: Cognitive regulation of performance: Interaction of theory and application. Attention and performance* (pp. 583-615). Cambridge: The MIT Press.

Craik, F. I. M., Byrd, M., & Swanson, J. M. (1987). Patterns of memory loss in three elderly samples. *Psychology and Aging, 2(1),*79-86.

Desrocher, M., & Smith, M. L. (1998). Relative preservation of egocentric but not allocentric spatial memory in aging. *Brain and Cognition, 37,* 91-93.

Ellis, N. R., Katz, E., & Williams, J. E. (1987). Developmental aspects of memory for spatial location. *Journal of Experimental Child Psychology, 44,* 401-412.

Folstein, M. F., Folstein, S. E., & McHugh, P. R. (1975). Mini Mental State : Practical method for grading the cognitive state of patients for the clinician. *Journal of Psychiatric Research, 12,* 189-198.

Gage, F. H., Dunnett, S. B., & Bjorklund, A. (1984) Spatial learning and motor deficits in aged rats. *Neurobiology of Aging, 10,* 43-48.

Gagnon, S., Winocur, G., & Di Francesco, S. (1996). Effects of cue manipulation on performance by old and young rats in a test of non-matching-to-sample. *Behavioral Processes, 37,* 157-165.

Gallagher, M., & Burwell, R. D. (1989). Relationship of age-related decline across several behavioral domains. *Neurobiology of Aging, 10,* 691-708.

Gronwall, D. M. A. (1977). Paced auditory serial-addition task: A measure of recovery from concussion. *Perceptual and Motor Skills, 44,* 367-373.

Hasher, L., & Zack, R. T. (1979). Automatic and effortful processes in memory. *Journal of Experimental Psychology : General, 108(3),*356-388.

Holdstock, J. S., Mayes, A. R., Cezayirli, E., Aggleton, J. P., & Roberts, N. (1999). A comparison of egocentric and allocentric spatial memory in medial temporal lobe and Korsakoff amnesics. *Cortex, 35(4),* 479-501.

Holdstock, J. S., Mayes, A. R., Cezayirli, E., Isaac, C. L., Aggleton, J. P., & Roberts, N. (2000). A comparison of egocentric and allocentric spatial memory in a patient with selective hippocampal damage. *Neuropsychologia, 38(4),* 410-425.

Kikusui, T., Tonohiro, T., & Kaneko, T. (1999). Age-related working memory deficits in allocentric place discrimination task: possible involvement in cholinergic dysfunction. *Neurobiology of Aging. 20,* 629-636.

Jue, D., Meador, K. J., Zamrini, E. Y., Allen, M. E., et al. (1992). Differential effects of aging on directional and absolute errors in visuospatial memory. *Neuropsychology, 6(4),* 331-339.

Kesner, R. P., Farnsworth, G. & DiMattia, B. V. (1989). Double dissociation of egocentric and allocentric space following medial prefrontal and parietal cortex lesions in the rat. *Behavioral Neuroscience,103(5)*, 956-961.

Masters, M. S. (1998). The gender difference on the Mental Rotations Test is not due to performance factors. *Memory and Cognition, 26(3),* 444-448.

Mayes, A. R., Meudell, P. R., & MacDonald, C. (1991). Disproportionate intentional spatial memory impairments in amnesia. *Neuropsychologia, 29,* 771-784.

McCormack, P. D. (1982). Coding of spatial information by young and elderly adults. *Journal of Gerontology : Psychological Sciences, 37*, 80-86.

Neuropsychological Laboratory. (1979) *Raven Progressives Matrices, Short form.* University of Michigan.

Naveh-Benjamin, M. (1987). Coding of spatial location information : an automatic process? *Journal of Experimental Psychology : Learning, Memory and Cognition, 13(4),* 595-605.

Naveh-Benjamin, M. (1988). Recognition memory of spatial location information : another failure to support automaticity. *Memory and Cognition, 16,* 437-445.

O'Keefe, J., & Nadel, L. (1978) *The hippocampus as a cognitive map.* London : Oxford University Press.

Ozekes, M. & Gilleard, C. (1989). Remembering faces and drawings : a test of Hasher & Zacks' model of automatic processing in a turkish sample. *Journal of Gerontology : Psychological Sciences, 44(4)*, 122-123.

Park, D. C., Puglisi, J. T., & Lutz, R.(1982). Spatial memory in older adults : effects of intentionality. *Journal of Gerontology : Psychological Sciences, 36,* 59-65.

Park, D. C., Puglisi, J. T., & Sovacool, M. (1983). Memory for pictures, words and spatial location in older adults : Evidence for pictorial superiority. *Journal of Gerontology : Psychological Sciences, 38,* 582-588.

Parkin, A. J., Walter, B. M., & Hunkin, N. M. (1995). Relationships between normal aging, frontal lobe function, and memory for temporal and spatial information. *Neuropsychology, 9(3),* 304-312.

Postma, A., & De Haan, E. H. F. (1996). What was where? Memory for object locations. *The Quarterly Journal of Experimental Psychology, 49A(1),* 178-199.

Postma, A., Izendoom, R., & De Haan, E. H. F. (1998). Sex differences in object location memory. *Brain and Cognition, 36(3),* 334-345.

Save, E., Poucet, B., Foreman, N., & Thinus-Blanc, C. (1998). The contribution of the associative parietal cortex and hippocampus to spatial processing in rodents. *Psychobiology, 26(2),* 153-161.

Schacter, D. L., & Nadel, L. (1991).Varieties of spatial memory : A problem for cognitive neuroscience. In R. G. Lister & H. J. Weingartner (Eds.), *Perspectives on cognitive neuroscience.* New York: Oxford University Press.

Tolman, E. C. (1948). Cognitive maps in rats and men. *Psychological Review, 55,* 189-208.

Uttl, B., & Graf, P. (1993). Episodic spatial memory in adulthood. *Psychology and Aging,* 8, 257-273.

Van der Stayy, F., & De Jong, M. (1993). Effects of age on water escape behavior and on repeated acquisition in rats. *Behavioral and Neural Biology, 60,* 33-41.

Woodin, M. E., & Allport, A. (1998). Independent reference frames in human spatial memory: body-centered and environment-centered coding in near and far space. *Memory & Cognition, 26(6),* 1109-1116.

Zelinski, E. M., & Light, L. L. (1988) Young and older adults' use of context in spatial memory. *Psychology and Aging 3(1),* 99-101.

Figure Caption

Figure 1. Disposition of the computer screens during encoding and retrieval of egocentric spatial information.

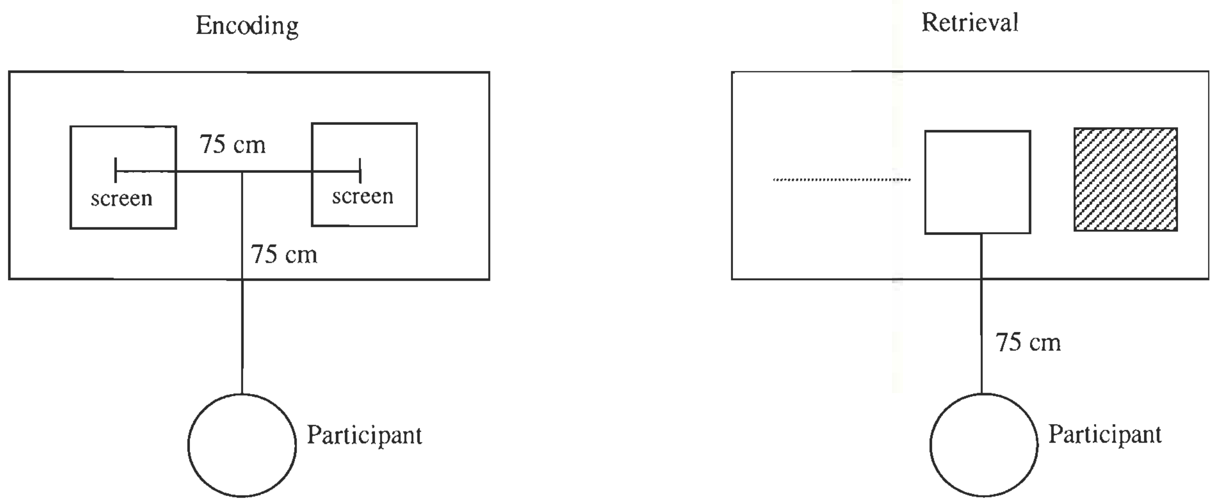

Table 1

Average Number of Positions Correctly Recalled in Experiments 1 to 4.

Experiment	M	SD	N
Experiment 1			
Incidental	54,30/60	3,83	20
Intentional	53,10/60	4,32	20
Experiment 2			
Double task	45,80/60	6,11	20
Simple task	50,60/60	6,12	20
Experiment 3			
Old	47,15/60	6,04	20
Young	51,75/60	4,84	20
Experiment 4			
First trial	51,75/60	4,84	20
Second trial	52,00/60	5,37	20