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Abstract

In this study, we compare the performance of young and elderly adults on egocentric and allocentric encoding tasks. Participants were asked to remember the spatial position of a target object placed on a 150 x 145 cm surface in order to relocate it on a second surface (100 x 160 cm) placed in an adjacent room. In the egocentric condition, the target object had to be relocated according to the participants' spatial position whereas in the allocentric condition, it had to be replaced in relationship to a second object which was displaced between encoding and recall. Participants' recall was assessed in terms of distance and angular deviation. Results show that older adults were impaired in relocating the object based on allocentric encoding. Particularly, estimation of the angular relation of the target and the reference point was deficient in older adults. In contrast, no such effect of age was observed in the egocentric condition. We also noticed that older adults were more sensitive to an interfering landmark in the egocentric condition.

Résumé

L'objectif de cette étude est de comparer la performance de jeunes adultes et de personnes âgées sur des tâches d'encodage d'informations spatiales égocentriques et allocentriques. On demandait aux participants d'encoder la position spatiale d'un objet cible placé sur une surface de 150 x 145 cm et de rappeler cette position sur une seconde surface (100 x 160 cm) installée dans une salle adjacente. Dans la condition égocentrique, l'objet-cible devait être repositionné en fonction de la position du participant alors que dans la condition allocentrique l'objet-cible devait être positionné en fonction de la position d'un second objet dont la position fut changée entre l'encodage et le rappel. Les résultats démontrent que le rappel des personnes âgées est inférieur dans la condition nécessitant un encodage allocentrique. Particulièrement, le rappel de la relation angulaire entre la cible et le point de référence était déficitaire chez les personnes âgées. À l'opposé, un tel effet d'âge n'a pas été décelé dans la condition égocentrique. Il a également été noté que les participants âgés ont fait preuve d'une sensibilité face à l'interférence provoqué par le déplacement de l'objet interférent dans la condition égocentrique.

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Encoding and remembering the location of objects enable us to comprehend and interact efficiently with the various objects of our environment. Remembering in which stall we parked our car in the supermarket parking lot as well as being able to walk around obstacles in our own house when the lights are turned off are obvious examples of behaviors that are based on the encoding of spatial positions. Although spatial memory is well developed and efficiently used in young adults, a number of studies have revealed that this aspect of our memory declines with old age (Uttl & Graf, 1993). For instance, older adults showed spatial memory deficits in tasks requiring to locate objects on a map (Sharps & Gollin, 1987) or drawings on a grid (Naveh-Benjamin, 1988). Therefore, it is essential to identify what are the cognitive processes involved in the encoding of spatial locations that decline with old age.

One way of looking at age differences in regards to spatial memory consists in dissecting how objects are located in space. Locating objects in the environment is extremely relevant to control actions directed at immediate surrounding objects such as grasping a ball, walking around obstacles or gazing at different structures of a scene (Shelton & McNamara, 2001). O'keefe and Nadel (1978) as well as other authors have depicted two frames of reference by which spatial co-ordinates of objects are processed, namely egocentric and allocentric encoding (Goodale & Murphy, 2000; Milner & Goodale, 1995; Paillard, 1991; Parkin, Walter & Hunkin, 1995). Egocentric encoding of space consists in estimating the location of an object based on our own spatial position. This type of spatial encoding requires the use of body-centered coordinates (Goodale & Murphy, 2000), which are used to estimate the distance and orientation of an object. However, egocentric information is extremely rigid and vulnerable to observer's displacements. The observer needs to keep a stable relationship in regards to the encoded location because if he/she moved between encoding and searching, his/her egocentric information would orient him/her toward a wrong location (Fiset, Gagnon & Beaulieu, 2000). In contrast, the encoding of allocentric spatial information enables the observer to estimate the locations of objects with respect to the position of landmarks in the environment. Allocentric encoding does not depend on the spatial stability of the observer as does egocentric encoding. Thus, in a situation where the observer moves from one viewpoint to another, he/she can still locate or recall the position of an object based on allocentric encoding by referring to the relative arrangement of landmarks (i.e. distances, angles and geometric spatial relationships between objects and landmarks). Consequently, the encoder's viewpoint becomes irrelevant in allocentric encoding and solely spatial relationships between landmarks and objects are encoded and later used to determine a spatial position.

In the present article, we used this distinction between egocentric and allocentric spatial encoding to evaluate how spatial encoding declines with old age. This issue has partly been addressed by other researchers. For example, Parkin, Walter and Hunkin (1995) have recently reviewed the relevant literature that examined the effects of old age on memory for object locations by using the distinction between egocentric and allocentric spatial encoding. The various spatial memory tasks that they surveyed were categorized as egocentric or allocentric. Spatial memory tasks that required left-right or bottom-top discrimination with regards to the participants' position were classified as egocentric tasks. For instance, Ozekes and Gilleard (1989) asked young and old participants to memorize the spatial location of images placed either to their right, to their left or in front of them. The stimuli were presented one by one for spatial encoding which was followed by a recall of each location in relation to the observer's position (right, left, and center). A similar task was elaborated by Parkin et al. (1995) where participants were told to discriminate and encode whether sentences were presented either to their right or their left on a computer screen. In a study performed by McCormack's (1982) participants had to discriminate the location of objects on a vertical plane (in one of 4 positions on a vertical axis). Finally, Ellis, Kats and Williams (1987) presented a succession of target objects in a 2x2 matrix placed in front of the participant. Each target position was recalled using both left-right and bottom top discriminations.

In contrast, spatial memory tasks in which the spatial locations of objects could also be determined by external landmarks or reference points were deemed allocentric tasks. For instance, Cherry and Park (1989) asked young and old participants to remember the position of 32 objects placed in a tower containing 4x4x4 compartments. Naveh-Benjamin (1988) assessed memory for spatial location recall using 20 pictures of objects placed in a 6x6 matrix. Spatial memory impairments associated with age were also observed by Zelinsky and Light (1988) in a study where participants had to remember the location of 12 structures that were placed on a schematic city map. In the three previous studies, young adults expressed higher recall scores than the older participants. Parkin et al., (1995) concluded that the age decrement was significantly larger in studies where encoding and recall of object positions were more markedly based on an allocentric frame of reference than on an encoding frame of reference.

Parkin et al. (1995)'s theoretical interpretation of age differences found in allocentric tasks is partly based on a process view and the notion of cognitive effort. This interpretation stipulates that allocentric encoding involves more complex and therefore more effortful encoding processes. This effort stems from the need to generate relations between the different spatial reference points whereas egocentric encoding implies only one spatial reference point, which is, the observer's position. Age related decline on tasks requesting an allocentric encoding could therefore be explained by older adults' limited cognitive resources (Craik, 1986; Craik, Byrd & Swanson, 1987). In contrast, age invariance in egocentric spatial memory tasks is explained by lower cognitive effort. In sum, referring to Hasher and Zack (1979)'s hypothesis regarding automatic and effortful cognitive processes, egocentric encoding is considered as a relatively automatic process.

However, the previously cited studies only provide indirect observations in support of the dissociation between egocentric and allocentric encoding of spatial information. In all the studies reviewed by Parkin et al. (1995), no manipulation was made in order to control the type of encoding used by participants upon accomplishing the task. For example, Desrocher (1998) concluded that memory for allocentric locations was more impaired in older adults, than was memory for egocentric locations. The cross-examination performed by this author included various tasks such as the study of intra-personal and extra-personal space, rotation tasks, manipulation of number of landmarks, and maze learning. Although the author concluded in favor of Parkin et al.'s (1995) interpretations, on many occasions deficits observed in older adults were of the same magnitude in both egocentric and allocentric conditions. On a few tasks, differences in the allocentric condition did not reach significance while with other tasks significant age differences were observed. This observation has a tremendous importance because participants often report using egocentric strategies while being tested in conditions that were designed to emphasize allocentric encoding (Desrocher, 1998). It is therefore often impossible to state that the subjects strictly used one type of encoding or the other.

In a recent study, Boucher (1999) asked participants to encode the location of 24 sets of 3 drawings of objects using an egocentric frame of reference (the right or left side of an imaginary vertical median line) or an allocentric frame of reference (relative locations of the presented pictures). After the 24 sets were studied and a 3 minute delay filled with a subtraction task, the drawings were presented again. In all cases the array of drawings appeared in a different location on the set up. Participants had to determine whether the location of the drawings was kept constant according to left-right discrimination criterion (did they remain on the encoding side of the invisible median line: egocentric) or whether the spatial relations (distance, angle, geometry) between the drawings was maintained or not (did the objects configuration change between encoding and recall: allocentric). Results indicated that the performances of older participants in comparison to the younger participants were significantly lower in both encoding conditions, a finding that does not support Parkin and al.'s (1995) interpretation. However, higher results were observed in young and older adults in the egocentric task suggesting that less cognitive effort was requested.

Boucher (1999) proposed a number of interpretations that could explain why age differences are often found in both egocentric and allocentric tasks. First, aging studies often focus on the memory component and for that reason participants are asked to remember numerous objects or drawings. In Desrocher's studies, the number of stimuli was often around 50. In object recognition tests older adults' scores are usually found to be significantly lower (Boucher, 1999; Desrocher, 1998). In such situations, the process of disentangling object memory deficits from spatial memory deficits becomes quite challenging

Furthermore, as mentioned by Desrocher (1998), no study has yet been able to design egocentric and allocentric memory tasks in which task difficulty was equated. This is also another important issue considering the fact that age differences increased on memory tasks as a function of the complexity of the stimuli. (Salthouse, Kausler & Saults, 1988; Sanders, Wise, Liddle & Murphy, 1990;) In most studies, the complexity of allocentric tasks is usually higher than it is for egocentric tasks (Boucher, 2000; Desrocher, 1998). In fact, many egocentric tasks correspond to left right discrimination based on the encoder's position, whereas allocentric tasks request the encoding of several parameters such as orientation, grouping, distance and angle relations between objects and several landmarks (Desrocher, 1998). Thus the significantly higher scores observed on egocentric tasks could be explained by their inherent lower complexity level (Boucher, 1999).

The previous criticisms also demonstrated that before focusing on the effect of old age on spatial memory tasks, it is absolutely essential that we examine how egocentric and allocentric information are processed when the memory requirements are minimized. In order to do so, the number of target objects should be significantly reduced and the delay between encoding and recall should be brief

With this in mind, the goal of the present study was to compare young and elderly adults' ability to process egocentric and allocentric information. In order to control the type of information which is to be encoded by participants, several methodological measures have been employed. For instance, task complexity in terms of the number of parameters that need to be assessed (angle, distance, objects, etc.) is equated and kept to a minimum for both conditions. Also, in an attempt to avoid soliciting object memory, participants will be asked to study only one object on successive trials. Finally, as the assessment of the processes involved in encoding spatial information stands as the focus of this task, the delay between study and recall was reduced to a minimum. We designed a task in which relocation of accuracy was tested in terms of distance and angular deviation.

Method

Participants

Twenty college students (10 women and 10 men) from the Université du Québec à Trois-Rivières aged 20 to 28 (M=23.55, SD=1.76) and 20 older adults (10 women and 10 men) aged 65 to 79 (M=71.05, SD=4.17) volunteered to participate in the study. Participants were not remunerated. Community dwelling older adults were recruited by advertisements in a local newspaper. Chosen participants reported having no neurological, psychiatric or drug/alcohol abuse antecedents at the time of testing as well as no known uncorrected vision deficits.

Material

Stimuli. Participants were asked to memorize the spatial position of a target object. The target object consisted of a 3,5 cm radius blue circle made out of cardboard and covered with a see through plastic film. The landmark reference point in the allocentric task and the interference object used for the egocentric task was a red cardboard circle with the same dimensions as the target object. A 1 x 4 cm black line was drawn in the center of the red circle and a black dot (1cm diameter) was drawn on one side of the line to provide orientation cues.

Setting. Stimuli were placed on two white opaque Plexiglas surfaces. Each surface was placed on one table for support. One surface was used for encoding and the other for recall. The encoding surface was 150 cm wide and 145 cm long whereas the recall surface's dimensions were 100 x 160 cm. We used two different surfaces between encoding and recall to prohibit participants from using the inherent geometric information of the surface as an allocentric cue (e.g., distance from one edge). On both surfaces a designated 98 X 98 cm perimeter was used to position the objects (see Figure 1). One edge of each surface was incised with a curved notch (50 cm wide X 15 cm deep at the center of the notch). The participant's chair was approached inside this incision in order to restrict his/her visual field to the surface. Participants took place on an adjustable chair and inclined their head toward a head chin rest that was fixed to the table. Testing took place in two adjacent rooms of similar dimension. The first room was used for encoding (230 X 360 cm) and the second for recall (250 X 360 cm). The surfaces were oriented differently in both rooms for the purpose of reducing the relevance of the geometric properties of the room as allocentric cues.

Insert Figure 1 here

Procedure

Consent and psychometric tests. Before starting the experiment, participants were informed of the goal of the experimental procedures and were invited to sign a consent form. Immediately after, participants verbally responded to a questionnaire investigating the exclusion criteria and completed the Vocabulary sub-test of the Wechsler Adult Intelligence Test-Revised (WAIS- R, Wechsler, 1981). The purpose of the vocabulary sub-test was to obtain an estimate of participant's verbal intellectual abilities. For the older adults, a screening test for general cognitive decline was also administered (Mini Mental State "MMS", Folstein, Folstein & Mc Hugh, 1975). Selected older participants all obtained a score superior to 25 on this test.

Egocentric and allocentric tasks. Participants first received explicit instructions and previewed a video exhibiting an example of the procedure used in both conditions in order to ensure that the task was fully understood. Participants were submitted to two experimental conditions : egocentric and allocentric. The two conditions were administered in a counterbalanced manner among participants.

Participants were submitted to 16 trials in each condition. Each trial unfolded as follows. Participants were invited to enter the first room and asked to take a seat on the chair facing the white surface harboring a head chin rest. They were told to rest their chin on the head chin rest and to close their eyes. The experimenter, standing on the side of the surface, positioned the blue circle (target object) and the red circle (interference object for the egocentric task or reference object for the allocentric condition). Ultraviolet (UV) marks on the surface, leaving a trace visible under UV lighting, were perceived only by the experimenter (none of the participants reported having noticed the UV marks on the boards) and indicated the precise locations where the objects had to be positioned. For each trial, the position of the target object varied on the encoding surface according to one of four pre-determined sequences. In order to designate where the circle would be placed, a 98 X 98 cm perimeter on the surface was subdivided in 7 X 7 cm squares in which the 7 cm diameter stimuli circles could be positioned. The perimeter was also subdivided in 49 X 49 cm quadrants (see Figure 1). The locations for the target circle were predetermined in a contingent manner, although, an effort was made so that the object was presented four times in each quadrant for a total of 16 trials. Circular marks of size comparable to the target or reference/interference objects had previously been made. When signaled, participants were granted 5 seconds to open their eyes and encode the position of the blue circle.

In allocentric trials, participants were instructed to precisely encode the position of the target (blue circle) in regards to its spatial relationships with the location of the reference object (the red circle). The encoding position of the reference object was constant throughout the 16 trials. In egocentric trials, participants were instructed to encode the position of the target object in relation to their own spatial position. From one trial to another, the location of the target circle varied but the position of the participant at one extremity of the surface remained the same throughout the experiment. This way, the same reference point was used for encoding the egocentric position of the target object just as only one possible allocentric reference point was available in allocentric trials. As for the interference object (the red circle) also presented on the surface in the egocentric condition, participants were told not to pay attention to it. The red circle that was used as an interference object in the egocentric condition was always placed in the same position for each trial and its purpose was originally to obtain equivalent same encoding conditions in both egocentric and allocentric tasks.

Immediately after encoding, participants moved to the adjacent room in order to recall the position of the target object on the second white surface on the edge of which a head chin rest was also installed. Again, the two circles were placed on the recall surface in predetermined marked positions by the experimenter. Where the red circle was positioned will be described below. As for the blue circle, the experimenter placed it alternately in one of the corners of the recall surface before the participant was asked to indicate where it was to be moved. The locations of the red circle as well as the blue circle for each trial was identified on the surface beforehand with marks also made with a UV marker. Participants were then asked to open their eyes and to indicate verbally to the experimenter in which direction to move the blue circle for it to regain its encoded position in relation to the reference point (the red circle also on the surface for the allocentric condition and his/her own position in the egocentric condition). The participant instructed the examiner to move the target either to the right, left, lower or higher on the surface.

For each trial, the position of the target object varied on the encoding surface according to one of four pre-determined sequences. In order to designate where the circle would be placed, a 98 X 98 cm perimeter on the surface was subdivided in 7 X 7 cm squares in which the 7 cm diameter stimuli circles could be positioned. The perimeter was also subdivided in 49 X 49 cm quadrants (see Figure 1). The locations for the target circle were predetermined in a contingent manner, although, an effort was made so that the object was presented four times in each quadrant for a total of 16 trials.

At the time of recall and for both egocentric and allocentric trials, the red circle placed by the experimenter on the recall surface stayed at the same position (egocentrically speaking, i.e., relatively to the participant's encoding position) on the surface (4 control trials) or was moved to a different location on the surface (12 experimental trials). For the allocentric condition, displacing the reference object ensured that the participants couldn't use their egocentric position as a reference point in order to recall the location of the target object. Displacing the interference object for the egocentric condition was a control procedure to maintain identical recall conditions in both egocentric and allocentric tasks. The same displacement protocol was used for both types of trials. The red circle was submitted to 4 types of displacements (4 trials per type of displacement), either 0 cm (control trials), 14 cm, 28 cm or 42 cm. The displacements could be made along, the X axis, the Y axis or diagonally.

At the end of the recall phase of each trial, the participant was asked to close their eyes and the experimenter noted the position of the target object as indicated by the participant by drawing a circle with the UV marker around the target object and by tagging the invisible circle with the trial number. When marking was done, the participant was told to open their eyes and to move to the encoding room for the beginning of the following trial.

For each trial, the participant's recall accuracy was assessed by calculating the position of the object (from its center) in relation to the X and Y axis of the recall surface. These measures were taken under a UV lighting after having completed the experimental conditions. These measures enabled us to estimate distance and angle deviations of the target object with respect to the specified reference point using the triangulation principle. In the egocentric condition, angle and distance deviations were calculated based on the participant's position (chin rest), whereas in the allocentric condition, the point of reference was the object of reference that served as a landmark.

Results

Scores obtained by young and older participants on the WAIS-R vocabulary sub-scale were compared. The analysis revealed that older adults demonstrated lower vocabulary scores (M=48, SD=1.1) in comparison to young adults (M=54, SD=2.06), $t(38) = 2{,}55$, $p<.05$. Because both age groups appear to differ in terms of verbal intelligence, as a first step, correlations between the vocabulary sub-test and spatial recall accuracy scores were computed in order to determine whether verbal intelligence had any influence on encoding of spatial positions (see Table 1). The analysis revealed that there were no significant correlations between test scores and spatial memory performance aside from a low but significant correlation between angle accuracy on experimental trials of the allocentric condition and vocabulary scores. Consequently, age differences on angle accuracy in the allocentric condition was examined using the vocabulary score as a covariable. The covariable had no influence on the results of the analysis and for that reason only the results of the analyses of variance will be described in the following section.

Insert Table 1 here

Data screening revealed a number of inversion errors. Therefore, before examining distance and angle accuracy, we first looked at the number of inversion errors in both egocentric and allocentric conditions. An inversion occurred when participants mistakenly inverted the targets horizontal (left/right) and/or vertical (upper or lower) position in relation to the reference point. Therefore, an error was considered as an inversion when the participant placed the target object in an opposed vertical and/or horizontal quadrant in relation to the reference object. In the allocentric condition, inversions were either horizontal or vertical or both, whereas, in the egocentric condition only horizontal (to the right or left of the participant) inversions could be made. The egocentric condition did not allow vertical inversions to occur since the participant (reference point) always sat facing the recall surface and remained at the same coordinates throughout the experiment (see Figure 2). It is to be noted, that targets placed within a 7 cm colliding zone on either side of the X and Y axes originating from the reference point, were not tallied as inversions, as an error margin was considered (see Figure 2). The length of the error margin corresponds to the diameter of the target object.

Insert Figure 2 here

An examination of the data indicates that more inversions were made by the older adults, specifically in the allocentric condition (See Table 2). In order to assess age differences on inversions, we used Fisher Exact Probability Tests to compare the number of participants who produced at least one inversion in each group. The Fisher Exact Probability test was selected because very few young adults produced inversion errors.

The analyses indicated that significantly more elderly adults made inversions in the allocentric condition ($p<.001$). When vertical and horizontal inversions were segregated, only inversions on the vertical axis yielded a significant age difference ($p<.001$). As said previously, virtually no inversions were made in the egocentric condition, and for that matter no age differences were observed.

Insert Table 2 here

It is obvious that inversion errors have a tremendous influence on the variability of the scores and consequently inflate the group averages. Although extremely meaningful, inversion errors were judged as extreme data and were eliminated for the computation of accuracy scores. Also, in an attempt to examine whether inversion errors had any effect on results, the database containing the inversion values was submitted to the same set of analyses as the database in which inversion values were eliminated. The results obtained were the same for both databases, although the results presented below relate to the database that excludes the inversion values. The resulting group means for both types of trials are presented in Figure 3 and Figure 4.

Insert Figures 3 and 4 here

For reasons already exposed, separate analyses were performed for egocentric and allocentric trials. Moreover, distance and angular deviations were examined separately.

Overall, four 2 (Age group) X 2 (Type of trials) mixed design analyses of variance (ANOVA) were computed.

On allocentric trials, young participants demonstrated better distance and angle estimation accuracy than older participants. The ANOVA calculated on distance accuracy revealed significant main effects of Age [$F(1,39) = 6.16$, $p<.05$] and Type of trial [$F(1,39) = 31.03$, $p<.001$]. This last result indicates that experimental trials induced larger distance deviations than control trials. No interaction between the two variables was obtained. The ANOVA performed on angle accuracy also indicated that there was a significant difference between the two age groups [$F(1,39) = 24.75$, $p<.001$], young adults showing better angle accuracy than older adults. As for the distance accuracy variable, the interaction between the two variables was not deemed significant.

On egocentric trials, the ANOVA performed on distance accuracy revealed that there was no significant age difference [$F(1,39) = 3.97$, n.s.]. However, the Type of trial factor was deemed significant [$F(1,39) = 12.41$, $p<.001$]. In general, participants performed better on control trials than on experimental trials. The Age group X Type of trials interaction also reached significance [$F(1,39) = 5.99$, $p<.05$]. The analyses of simple main effects indicated that younger adults were more accurate on experimental trials than older adults [$F(1,39) = 15.56$, $p<.001$]. Moreover, older adults showed lower accuracy scores on experimental trials in comparison to control trials [$F(1,39) = 17.82$, $p<.0001$].

Similar results were obtained on angle accuracy scores on egocentric trials. The ANOVA revealed significant effects of Age group and of Type of trials. Average angle accuracy was significantly lower in older adults [$F(1,39) = 11.21$, $p<.05$]. In addition, accuracy scores were better for the control trials [$F(1,39) = 15.15$, $p<.001$]. The Age group X Type of trials was also found to be significant [$F(1,39) = 5.02$, $p<.05$]. The analyses of simple main effects indicated once again that older adults expressed lower accuracy than young adults on experimental trials [$F(1,39) = 15.50$, $p<.001$] and that performances on experimental trials was lower than on control trials for the group of older adults only [$F(1,39) = 18.80$, $p<.0001$]. This last set of analyses indicate one more time that all the effects were caused by the difficulties that older adults faced while relocating the target objects on experimental trials.

Discussion

Results from this study reveal that in the allocentric encoding condition, older adults' object relocation accuracy was significantly lower when compared to that of younger adults based on both distance and angular deviation scores. A strikingly different pattern of results was obtained on egocentric trials. Our findings indicate that the ability to encode spatial locations based on egocentric coordinates does not fluctuate with age when the surrounding environment within the visual field remains stable between encoding and recall. Interestingly, we observed that when the interference object changed location between encoding and recall, distance and angle estimation based on egocentric cues significantly decreased in older adults.

In the present research we designed a constrained encoding situation in order to control the type of encoding (allocentric or egocentric) that could be used by the participants. As such, we have attempted to eliminate extraneous factors (e.g. limited number of target objects to be remembered, short delay between encoding and recall, comparable task complexity) in order to examine the effect of normal aging on the specific processes involved in spatial encoding. Overall, observations extracted from these carefully controlled encoding situations confirm Parkin et al.'s (1995) predictions that allocentric encoding declines with old age, whereas egocentric encoding seems much less affected.

Our findings concur with some of the data obtained by Desrocher (1998; Desrocher & Smith,1998) who examined the effect of old age on memory for egocentric and allocentric spatial information across several paradigms. For instance, in a rotation task where participants had to relocate objects from a different point of view than where they stood while studying the objects, they found that aging leaves memory for egocentric information unaltered but impairs memory for allocentric information.

Similar remarks were brought up by Boucher (2000). As stated earlier, he also noticed that participants succeeded better on the egocentric than on the allocentric task. He concluded that the high number of objects that participants needed to study could explain the age difference. He also speculated that allocentric tasks are more difficult intrinsically because of the number parameters that need to be accounted for in order to locate an object. Using only one objet to be remembered and only one point of reference, our results enable us to conclude that, in fact, normal aging affects distinctively the processes underlying allocentric and egocentric spatial encoding.

In order to further investigate this conclusion, we had originally planed to compare young and older adults' performances on both encoding conditions (egocentric versus allocentric) in order to investigate whether age differences on egocentric or allocentric tasks emanate from the different cognitive processes involved rather than task difficulty. Unfortunately, because of methodological differences strict comparisons between allocentric and egocentric recall performances were irrelevant. In fact, on the distance variable, the maximum distance separating the target object from the reference point was 42 cm in the allocentric condition compared to 94.5 cm in the egocentric condition. Moreover, on the angle variable, the target object could be placed in a 360° array around the reference point whereas in the egocentric condition, only a 180° array was possible given the observer's position. In this sense, the error margin was unequal in both conditions making any statistical comparisons meaningless. In fact, mean deviations values presented in Figures 3 and 4 concur with this observation. Mean distance deviation values are greater in the egocentric condition, whereas mean angle values are greater in the allocentric condition. Nevertheless, independent statistical analysis yielded very interesting findings.

Indeed, when spatial memory was based on an allocentric frame of reference older adults appear to struggle with the estimation of distance and angle. Particularly, estimation of the angular relation between the target object and the reference object was quite impaired in elderly adults. This observation allows us to distinguish distance estimation and angle estimation as two distinct processes involved in allocentric encoding. Prior studies (Kirasic, 1989 ; Kirasic, Allen & Siegel, 1984) also support the idea that orientation and distance information are processed separately. Kirasic (1989) compared the performance of young, middle-age and elderly adults on cognitive tasks involving the solution of spatial processing problems. In her experiment, participants studied the spatial location of an array of 9 pictures of buildings from the center of a room, after which they were asked to indicate the direction and distance of six pictures in relation to a designated sighting location under instructions of either perspective-taking (imagining they had moved to a different spatial location) or mental rotation (imagining the rotational movement of the array). Their results revealed a significant age effect where older adult's performances were markedly less accurate for estimation of the orientation (or angle deviation) compared to young and middle age adults. As for the distance variable, the author states that despite findings of an age related difference, the estimated-to-actual distance correlations revealed a very high level of accuracy for all three age groups. Therefore, Kirasic's (1989) results combined with our findings suggest that not only are distance and angle spatial relations processed differently, it also seems that processing allocentric angular information is cognitively more challenging than processing allocentric distance relations.

Further support to this observation is provided by the inversion errors noticed almost exclusively in the allocentric condition and predominately in the older age group. Indeed, significantly more participants made inversion errors in the allocentric condition. An inversion error consists in mistakenly placing the target object in an opposed vertical and/or horizontal quadrant in relation to the reference object. These errors result from angular spatial relations being incorrectly processed and appear essentially in the elderly adults' performances. Therefore, the markedly greater inversion errors observed in the older adult's performances support the hypothesis that older adults' ability to estimate angles in an allocentric frame of reference suffers from a lack of accuracy. Moreover, it seems that older adults struggle particularly with the vertical angular relation of a target in reference to a landmark. When looked at separately, vertical inversions yielded an age difference while horizontal inversions did not. Nonetheless, our findings in the egocentric condition answer the question as to whether angular estimation accuracy deficits in older adults are generalized or not. In fact, in control trials, older adults' recall of angular relations and distance reached levels comparable to young participants. This finding suggests that the ability to process angular information in older adults looses its efficiency when based on an external reference object (allocentric condition).

On a different note, a type of trial effect was also disclosed in the allocentric condition for the distance variable. This finding indicates that distance estimation for both groups was less accurate for experimental trials in which the red reference circle was displaced from its original position in relation to the participant's position on the encoding surface. To that effect, one could argue that experimental trials require a form of spatial updating and transformation of the memory trace contrary to control trials where the egocentric position in relation to the observer stays stable at recall. Spatial updating is considered as the ability to keep track of changing spatial relations between objects (Pick & Rieser, 1982). Recalibration of encoded information demands a certain amount of cognitive effort and inevitably leads to a certain error margin. In contrast, the control trials are exempt from this recalibration process and therefore, deviation from the correct values of distance and angle relations should be lesser compared to experimental trials. Unfortunately, the analyses of the angle variable for the allocentric condition did not yield a similar Type of trial effect. Although a similar conclusion could be drawn based on younger adults' performances, it does not apply to accuracy scores of the old age group. Indeed, older adults' performance for angle estimation was more accurate in experimental trials. As discussed earlier, older adult's estimation of angle in allocentric trials is massively impaired (e.g. inversion errors) and suggests that processing angular relations in stable and unstable conditions is cognitively challenging. This finding definitely deserves further attention.

Another interesting but unexpected finding provides information on older adults' spectrum of impairment in spatial memory tasks. Although our results convincingly suggest that egocentric processing is unimpaired in old age, experimental trials in the egocentric condition yielded a striking result. We found that distance and angle estimation were less accurate for the older group in the experimental trials. In these trials the red reference circle was displaced upon recall. Participants were told not to pay attention to the potential displacement of this interfering object. Nevertheless, it did influence older adults' recall accuracy. A finding that could indicate that older adults are more sensitive to an interfering landmark compared to young adults as manipulating the interfering object did not influence young adults' distance and angle accuracy scores. Results suggest that in this task young adults succeeded in not taking the red circle in consideration in the encoding and recall processes while older adults did not. In this sense, one could argue that the red circle's modified position acted as an interfering factor upon recall and older adults were more sensitive to this interference in their visual field as they tried to recall the encoded egocentric position. Previous studies provide explanations that could account for this sensitivity to an interfering factor. Folk and Lincourt (1996) and Madden, Pierce and Allen (1996) characterized the age effect in tasks involving an interference factor in terms of a decrement in older adults' active inhibition of distracter information during visual search tasks. In fact many studies assessing age differences in the selectivity of visual information processing have put forth that non-targets produced larger interference effects for old compared to young (Schialfa, Esau, & Joffe, 1998; McDown & Filion, 1995; Scialfa & Harper, 1994; Plude & Hoyer, 1986).

At this point, we turn back to Parkin et al.'s (1995) interpretations of spatial memory deficits in old age and to Hasher and Zacks (1979) view of spatial memory. As stated earlier, Parkin et al. (1995) speculated that egocentric encoding might not fluctuate with age because of its rather automatic nature. In partial agreement with this interpretation, our findings suggest that the ability to encode and recall egocentric information does not fluctuate with age. However, we can hardly conclude that this type of encoding is fully automatic based on the results of the experimental trials, which indicate that elderly participants were impaired when the interfering object moved between encoding and recall. It must be noted that this mild manipulation in the visual frame of reference seemingly did not affect young adults' performance. However, previous studies performed with young participants have also showed that even young adults' performances for judging egocentric relations between the observer and a target seem to be distorted by changing available allocentric information (Sterken, Postma, de Haan & Dingemans, 1999; Sterken, 1997; Bridgeman,1991). Obviously, the effect was not powerful enough to disturb young adults' encoding but it did influence the elderly participants. One should also keep in mind that this manipulation was not designed with the spirit of interfering with the egocentric encoding. This finding suggests that somehow the memory trace generated during egocentric encoding includes a number of elements other than the target object. At recall, if the interfering object moved, older adults' recall was biased. We propose two interpretations for this observation. The first interpretation associates the impairment to a failure of excluding spatial information associated with the interfering object while encoding which could be caused by a lack of inhibition. On the other hand, it is also likely that the memory trace is composed of several elements but older adults present a greater level of difficulty in trying to discard information pertaining to the interfering object. Further empirical investigation will help to resolve this issue.

In conclusion, Parkin's assumption that aging influences distinctively the processes involved in encoding egocentric and allocentric spatial information is supported. Adopting an allocentric frame of reference in order to encode the position of a target in space triggers deficits in older adults' ability to process distance and angular relations between the target object and an external landmark. Encoding of egocentric spatial information seems rather unaltered in old age when the observer's position and its surrounding environment remains stable.

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Table 1

Pearson's *r* between the vocabulary subtest of the WAIS-R and spatial recall accuracy scores

	Egocentric/ Distance/ Control	Egocentric/ Distance/ Experimental	Egocentric/ Angle/ Control	Egocentric/ Angle/ Experimental
Vocabulary	0,04	0,26	0,31	0,20

	Allocentric/ Distance/ Control	Allocentric/ Distance/ Experimental	Allocentric/ Angle/ Control	Allocentric Angle Experimental
Vocabulary	0,01	0,04	0,03	-0,34*

* p = < .05

Table 2

Number of participants who produced inversion errors in egocentric and allocentric trials.

	Egocentric		Allocentric	
	Young	Old	Young	Old
No inversion	18	19	17	7
At least one inversion	2	1	3	13*
Total	20	20	20	20

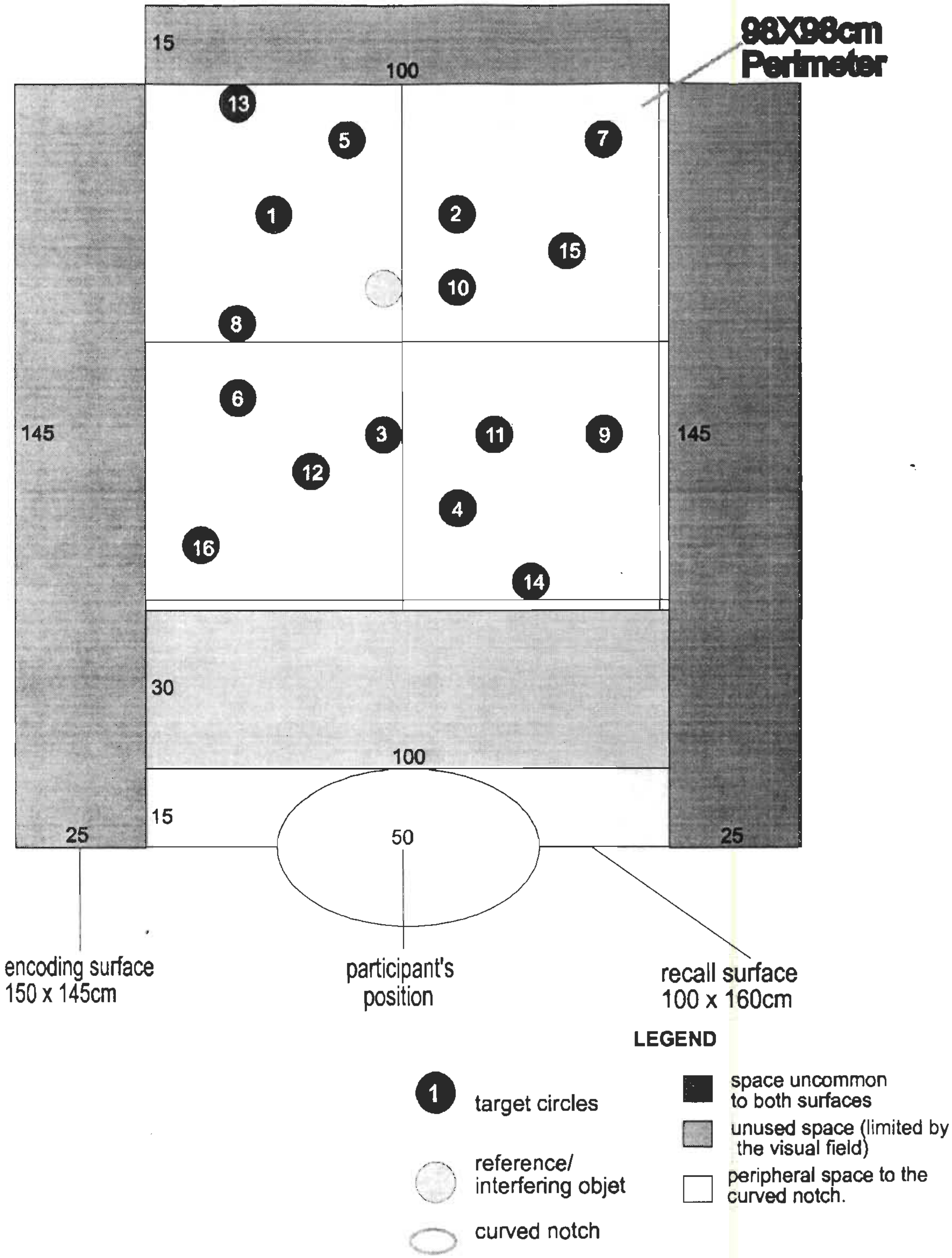
*Fisher's Exact Probability Test, $p<.001$

Figure Caption

Figure 1. Schematic representation of the encoding and recall surfaces. Figure 2. Examples of an inversion in egocentric and allocentric conditions.

Figure 3. Mean deviation of target displacement (distance and angle) in the allocentric condition for control and experimental trials (error bars = standard deviation).

Figure 4. Mean deviation of target displacement (distance and angle) in the egocentric condition for control and experimental trials (error bars = standard deviation).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Perimeter
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100
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5
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145
145
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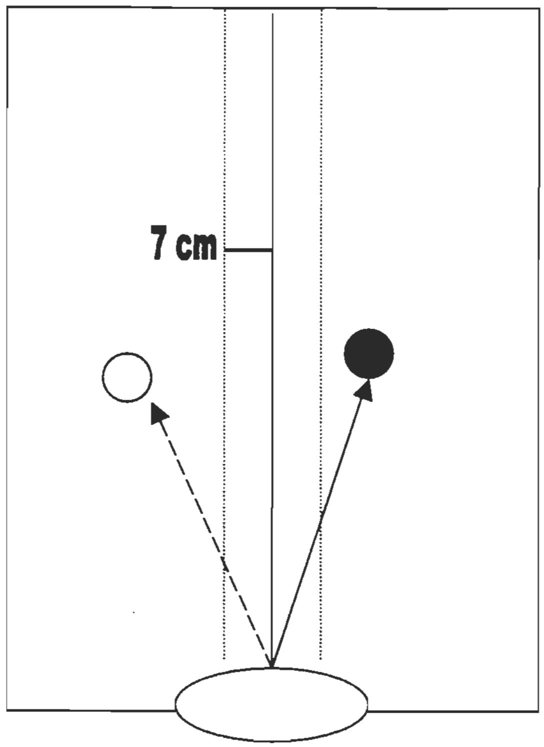
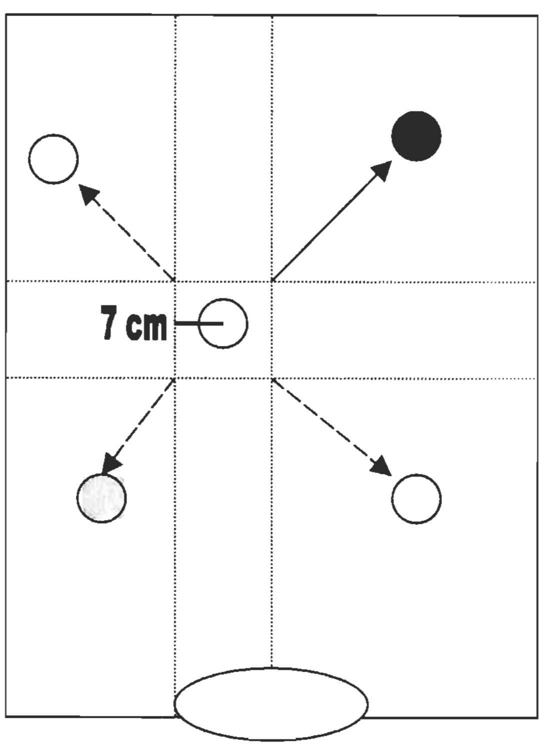
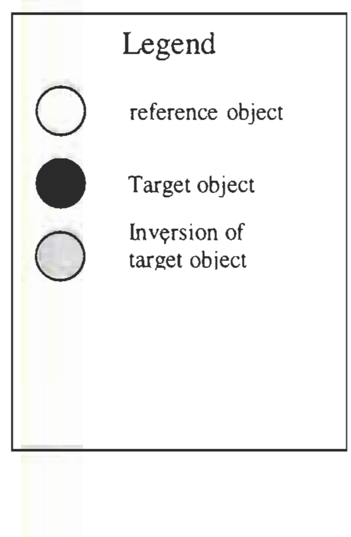
25
25
encoding surface
150 x 145cm
participant's
position
recall surface
100 x 160cm
LEGEND
1
target circles
reference/
interfering objet
curved notch
space uncommon
to both surfaces
unused space (limited by
the visual field)
peripheral space to the
curved notch.

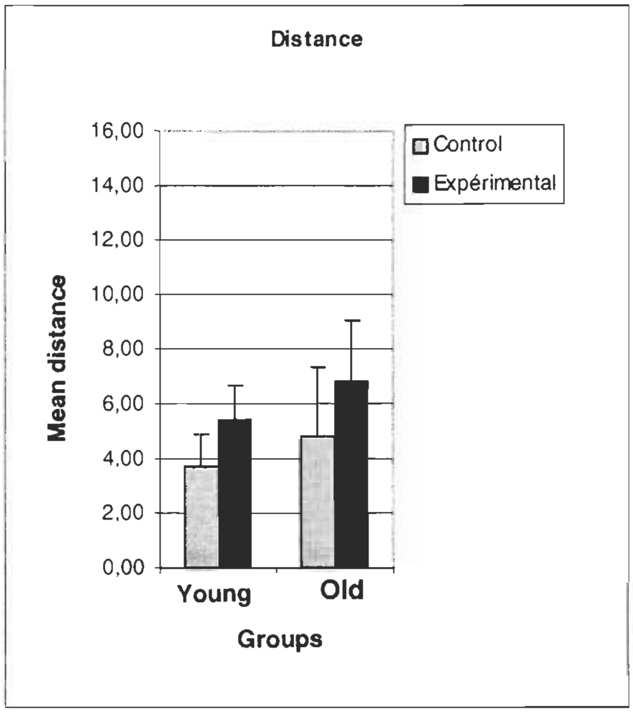
Example of an inversion in the egocentric condition.



Example of an inversion error in the allocentric condition.



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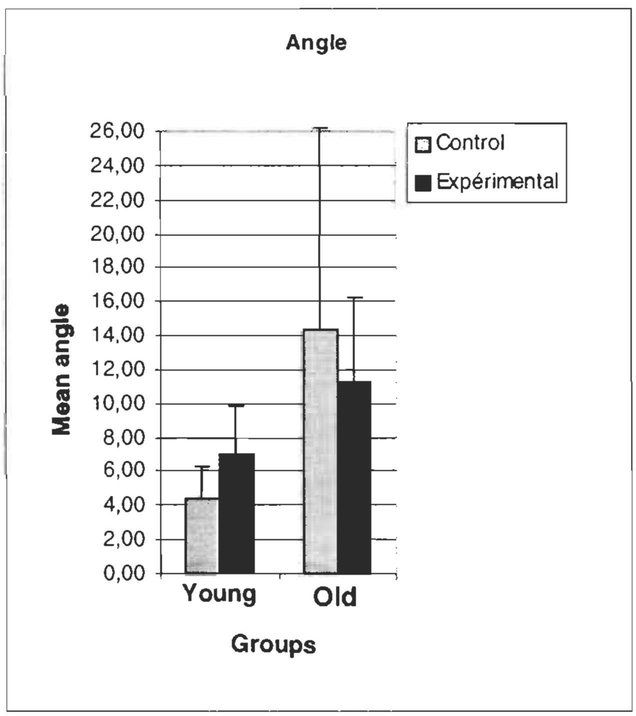
Angle
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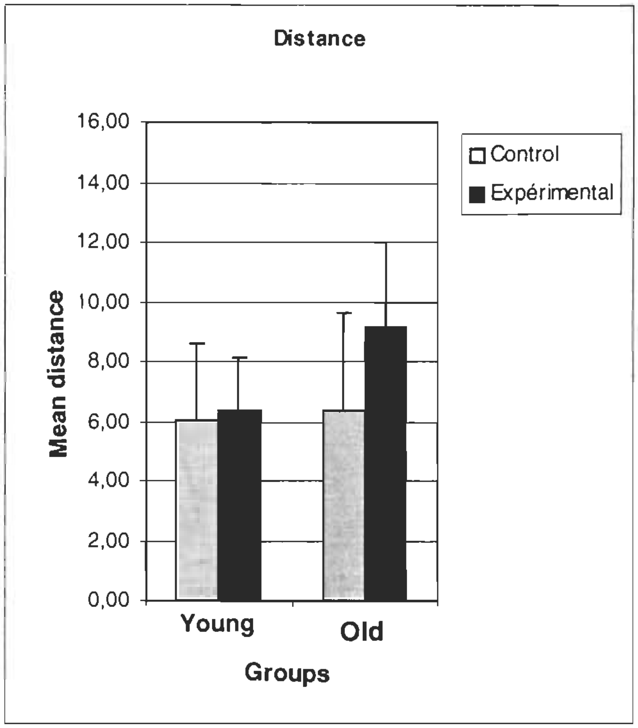
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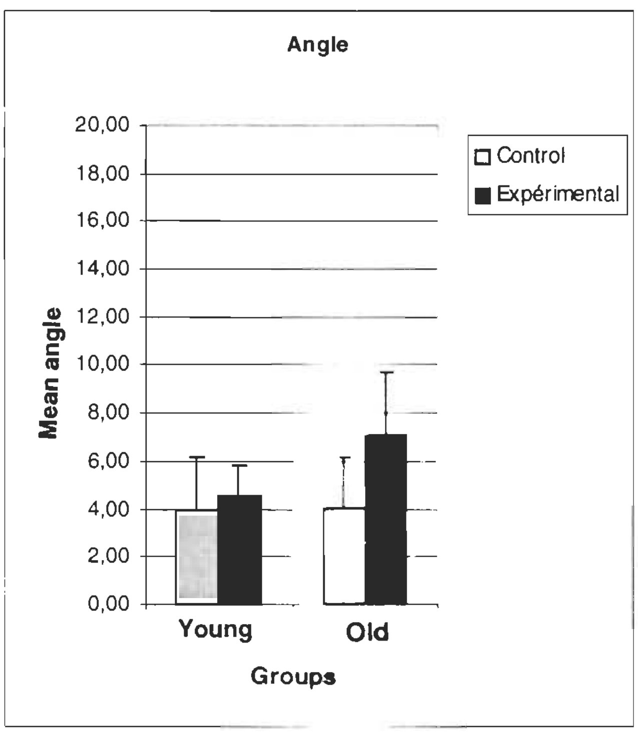
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