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Real and Imagined Movements in Older and Younger Adults

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Older and younger adults completed tapping tasks using real and imagined movements. Two types of tasks were utilized, repetitive movements to a single target and sequential movements around a series of targets. For repetitive movements, real and imagined performance was similar; however, for the sequential task older adults showed greater changes with increasing difficulty for real movements but not for imagined movements. Older adults showed a general slowing on all tasks compared to younger adults, but the results suggest some age-related changes relate specifically to the execution of a discrete series of movements.

As Jeannerod and Frak (1999, p. 735) suggest, "Motor imagery is now becoming a hot topic in the field of cognitive neuroscience." One reason for this is that it appears to offer insight into aspects of the motor system decoupled from the physical execution of actions. New findings and new methodologies have offered major insights into the covert aspects of motor performance (Jeannerod & Frak, 1999; see Gibbs & Berg, 2002, for a discussion of the importance of motor processes for understanding imagery). Factors impacting real movements, such as awkward postures and biomechanically plausible trajectories, have been seen to affect imagined movements (e.g., Parsons, 1987, 1994). Research suggests that imagined movements utilize the same brain mechanisms as real movements (e.g., Sirigu et al., 1996; Gerardin et al., 2000). Such results suggest parallels between work comparing real movements to imagined movements and the seemingly analogous, but more widely investigated, relationship between visual perception and visual mental imagery (for more discussion see Jeannerod, 1994).

One method that can be used to study motor performance relies on Fitts' law (Fitts, 1954). The central element of Fitts' law is the Index of Difficulty of a movement. A movement will be more difficult if the target is smaller rather than larger, and a movement will also prove more diffi-

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cult if the target is farther away rather than nearer. These two factors that contribute to the Index of Difficulty (ID), width of the target (W) and movement amplitude (A), are combined in the equation: $ID = \log2(2A/W)$. Movement Time (MT) is a linear function of Index of Difficulty, and hence is given by the equation: $MT = a + b[\log2(2A/W)]$. The law, therefore, predicts a regression line based on movement difficulty, and conformity to Fitts' law can be ascertained by assessing the goodness of fit to the predicted line. As distance is held constant and target width decreases, movement time increases.

It has been found that both real (physically executing a movement) and imagined (mentally imagining the performance of a movement) movements adhere to Fitts' law (Sirigu et al., 1995; Decety & Jeannerod, 1996). This means that, unlike visual imagery studies in which latencies are a simple linear function of distance (e.g., mental rotation, Shepard & Metzler, 1971; mental image scanning, Kosslyn, Ball, & Reiser, 1978), imagined movement latencies conform to a more complex, logarithmic function and thus would be much harder to generate from guesses or estimates. Based on the fact that they can offer unique insights into the motor system, imagined movements have been used to study motor performance in a variety of populations (e.g., Danckert et al., 2002; Maruff, Wilson, Trebelicock, & Currie, 1999; Maruff & Velakoulis, 2002).

Age-Related Changes in Psychomotor Performance

One area of performance that consistently has shown decline with advancing age is the slowing of responses (for reviews, see Salthouse, 1985; Welford, 1984). It does appear that several different deficits exist (see Seidler & Stelmach, 1995), although how pronounced decrements are with aging remains an issue of some debate (e.g., Kerr, Blais, & Toward, 1996). Previous studies have shown changes in Fitts' law performance with increasing age (e.g., Goggin & Meeuwsen, 1992; Welford, Norris, & Shock, 1969; York & Biederman, 1991). In general, steeper slopes for Fitts' law functions have been observed for older adults, and the impact of aging on the slope rather than just the intercept suggests that movement-specific components have been affected.

Since motor imagery has the potential to both examine and possibly improve motor functioning (Jeannerod & Frak, 1999), it seems worth applying it to age-related changes in motor performance. Imagined movements can be carried out with the exact same targets and likely recruit the same brain areas involved in physically executed movements. If imagined movements show the same general pattern of age-related declines in performance with increased target difficulty, then accounts of the influence of age on psychomotor performance can concentrate on aspects common to both real and imagined movements. On the other hand, if imagined movements do not show age-related declines, then the type of explanation possible for changes in motor execution will be constrained to those aspects of performance not common to both real and imagined movements.

The current study utilizes simple tapping tasks with real and imagined hand movements to examine age-related differences in physical versus imagined motor movements. Age-related differences in motor performance seem to prove most important when a sequence of actions is required (Liao, Jagacinski, & Greenberg, 1997). However, previous research on imagined movements thus far has not developed standardized tools for assessing changes in motor performance for simple versus more complex series of actions. Therefore, in addition to utilizing a standard repetitive (requiring a single type of movement) tapping task for real and imagined movements, this paper also includes a new type of sequential (requiring a sequence of multiple movements) tapping task.

Method

Participants

Fourteen older adults were recruited from local senior centers and independent senior living apartments. The participants were volunteers and were not compensated for their participation. The older adults ranged in age from 62 years to 88 years (mean=74.4 years). Fourteen younger adults were recruited from students obtaining partial credits for a General Psychology class. The younger adults ranged in age from 18 years to 26 years, (mean=21.5). Selection criteria excluded subjects who reported any impairment of the hands or wrists, any previous head trauma, any history of psychiatric illness and any form of color blindness.

Materials

Participants were presented with a sheet of 8½ x 11 in. paper with the target box or target boxes printed on it. The repetitive task employed materials of a type used in previous research (e.g., Maruff et al., 1999). On the left side of each sheet there was an 80mm by 1mm vertical line. To the right of the line was a single, black, target box with its closest side 30mm from the line. Five different-sized square target boxes were used: 30mm, 14.9mm, 7.5mm, 3.7mm or 1.9mm in width.

For the sequential task, on each sheet of paper five identically sized boxes were arranged in an hourglass shape (two boxes on the top, one in the middle, two boxes at the bottom; see Figure 1). One of the boxes, determined randomly for each participant, was colored red to denote a starting square and the other four boxes were colored black. The same five target box sizes employed in the repetitive task were used for the sequential task. The boxes were arranged so that the nearest edges of the outside boxes were 30mm from the center of the middle box and 30mm from the inside edge to the center of each other.

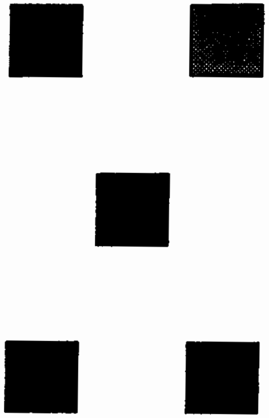

Figure 1. Example of a sequential stimulus (actual stimuli used a red, not a gray, box to denote starting square)

Procedure

Older and younger participants carried out both repetitive and sequential movements. For both types of movement, participants performed two different conditions: physically executing the movements ("real") or imagining themselves executing the movements ("imagined"). For real repetitive movements participants began with a stylus to the left of the vertical line. Participants were instructed to produce 5 consecutive, continuous movements of the stylus. A single movement consisted of moving from beyond the line, tapping into the box, and moving back beyond the line from where a subsequent tap was performed. Participants were asked to perform each movement as quickly as possible while maintaining accuracy. For imagined movements, participants were asked to imagine holding the stylus and executing the physical actions involved in the same type of motions required for the real movements. All types of trials commenced when the researcher said, "Go," and the participants counted aloud either their real or imagined movements. A stopwatch was used to record latency. Within these tasks the accuracy of movements was not recorded; indeed, for imagined movements accuracy could never be assessed, but participants were instructed to make sure taps did occur within the box every time.

For sequential trials, real movements required participants to begin with the stylus in the red colored box. They then used six consecutive movements to trace a circuit around the hourglass layout of boxes, tapping within each black box along the circuit (see Figure 2). The direction of movement (clockwise versus counter-clockwise) was randomly assigned. Participants were instructed to give a running count at the end of each circuit, and continuous movements lasted until they had completed five circuits. As with the repetitive movements, for imagined movements participants imagined holding the stylus and executing the physical actions involved in the same type of motions required for the real movements. Again, all trials commenced when the researcher said, "Go," and the participants counted aloud either their real or imagined movements. A stopwatch was used to record latency.

All participants completed all the repetitive movements first, and then engaged in the sequential movements. Within each condition participants began with the largest size boxes, progressing in order on to the smaller ones. The order of physically executing movements versus imagining carrying out the same movements without making any physical actions was counterbalanced across subjects. Each participant was given one demonstration and one opportunity to practice for both repetitive and sequential trials.

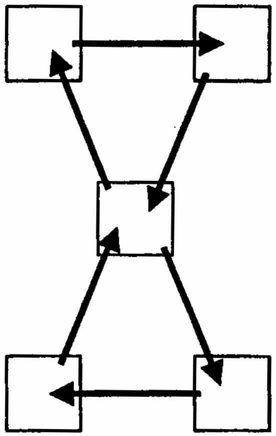

Figure 2. Example of a clockwise movement sequence for the sequential task.

Results

For both repetitive and sequential movements, mixed ANOVAs were conducted looking at latency of movements by group (young versus old), condition (real versus imagined movements) and the five target sizes. Target sizes from 1.9mm to 30mm produced Fitts' law index of difficulty (ID) of 1, 2.01, 3, 4.02, and 4.98 respectively (which are reported rounded to the nearest whole number in the rest of the analyses). There were some departures from sphericity, and Geisser-Greenhouse corrections were used for those tests.

Repetitive Movements

For repetitive movements, in terms of the central question of whether real and imagined movements for younger versus older adults show similar trends with increasing difficulty, there was no hint of a group by target size interaction (*F*(4, 104)=1.12, *p*>.05, partial η^2=.04), nor a group by condition by target size interaction (*F*(4, 104)=1.35, *p*>.05, partial η^2 =.05; see top panels of Figure 3). Thus, although there appears to be some general slowing in the repetitive movement task for older adults[1], with real movements more impacted than imagined movements (suggested by interaction of group and condition reported below), these effects do not relate to the difficulty of the movements.

In terms of assessing the adherence to Fitts' law, there was a main effect of target size, with smaller targets inducing slower movements (*F*(4,104)=22.73, *p*<.05, partial η^2=.47, MSE=0.42 means: ID1=3.80 seconds, ID2=3.79, ID3=3.84, ID4=4.26, ID5=4.73). As expected from Fitts' law these points follow a linear regression line (R^2=.80). Longer than expected latencies for targets with a low index of difficulty have been noted in previous work (see Welford, 1960). However, in this case the longer latencies compared to the next target's size likely also reflect a practice effect on the task. All participants progressed from largest to smallest targets in order. Excluding the largest target and looking at just the last four target sizes produces an improved fit (R^2=.91). As mentioned above, there was a main effect of group, with younger faster than older participants (*F*(1,26)=25.12, *p*<.05, partial η^2=.49, MSE=4.01; means=3.5 vs. 4.7 seconds. A significant interaction between group and condition was found (*F*(1,26)=7.31, *p*<.05, partial η^2=.22). Younger participants were faster on real movements than imagined movements (means= 3.3s vs. 3.7s), whereas older participants performed at the same speed on real movements and imagined movements (means =4.8s vs. 4.6s).

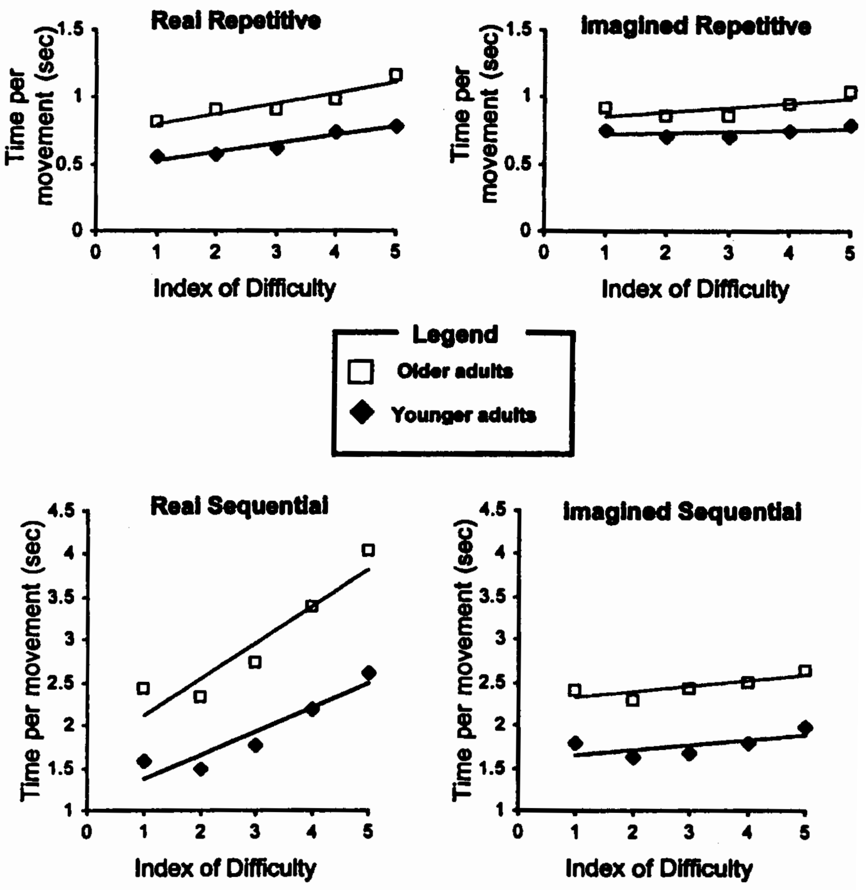

Figure 3. Fitts' law plots for real and imagined Movements in younger versus older adults.

There was also a significant interaction between target size and condition (*F*(2.89,75.12)=11.17, *p*<.05, partial η^2=.30, MSE=0.26). The means for imagined movements show longer than expected latencies for the largest target sizes (a linear regression line suggests some deviation from Fitts' law, R^2=.41), whereas the real movements follow a linear trend very closely (R^2=.93). This suggests that the practice effect observed occurred principally in the imagined condition. A regression line for the imagined

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[1] Independent analyses of the real movement data and the imagined movement data confirm main effect group difference within both conditions. Hence, the main effect of group does not appear to be driven solely by the interaction of group and condition.

movement data excluding the initial target size improved the fit substantially (R^2=.88).

Sequential Movements

With the sequential movements a different pattern of results emerged, and, crucially, the 3-way interaction between group, condition and target size was significant (*F*(4, 104)=4.23, *p*<.05, partial η^2 =.14; see bottom panels of Figure 3). Perhaps the easiest way to illustrate this change across target sizes is to look at the gradients of the regression lines through them. Younger and older adults have similar gradients for imagined movements (gradients = 0.28 vs. 0.33) but for real movements younger adults show much lower increases in movement time to smaller targets than do older adults (gradients = 1.37 vs. 2.12).

Again, assessing the correspondence of these data to Fitts' law, there was a main effect of target size, with smaller targets inducing slower movements (*F*(1.67,43.52)=60.37, *p*<.05, partial η^2=.70, MSE=7.05; means: ID1=10.3s, ID2=9.7, ID3=10.7, ID4=12.3, ID5=14.1). As predicted, these data conform well to Fitts' law, with another reasonable fit for a linear regression line (R^2=.83). As seen with the repetitive movements, longer latencies were observed for the largest target size compared to the next target size. Again, we believe this probably reflects a practice effect on the task (excluding the initial target size increases the regression line fit to R^2=.99).

A group by condition interaction was found (*F*(1,26)=7.31, *p*<.05, partial η^2=.18). Younger adults showed no significant difference between real and imagined movements (means=9.7s vs. 8.9s), whereas older adults tended to be slower for real movements than imagined movements (means=14.9s vs. 12.3s). This interaction is also reflected in the main effects, with younger participants faster than older participants (*F*(1,26)=22.93, *p*<.05, partial η^2=.47, MSE=56.56; means=9.3s vs. 13.6s), while real movements were slower than imagined movements (*F*(1,26)=20.45, *p*<.05, partial η_2=.44, MSE=10.01; means=12.3s vs. 10.6s). Overall the main effect of group and the group by condition interaction suggest that, as with repetitive movements, there does appear to be some general slowing in the sequential movement task for older adults. Once again, for older adults physical execution was more impacted than imagined movements.

There was also a significant condition by target size interaction (*F*(2.07,53.83)=59.52, *p*<.05, partial η^2=.70, MSE=2.52). The gradient of the line for real movements as a function of target difficulty was steeper than that for imagined movements. The real movements mirror Fitts' law (R^2=.88) more closely than the imagined movements (R^2=.54), but again, excluding the first target size substantially improves the fit (R^2=.99 and .97 for real and imagined movements, respectively).

Matched Subsets of Participants

Although an interaction between group, condition and target size was found for sequential movements, the effect observed may be an amplification of the naturally occurring trend. Converting the raw response latencies to percentage increases (based on the response time to the initial target size) produces almost identical tendencies for the younger and older adults' movements (see Figure 4). Changes in executing sequential movements seen with increased age follow the same general trend as those for younger adults but with some consistent cost added.

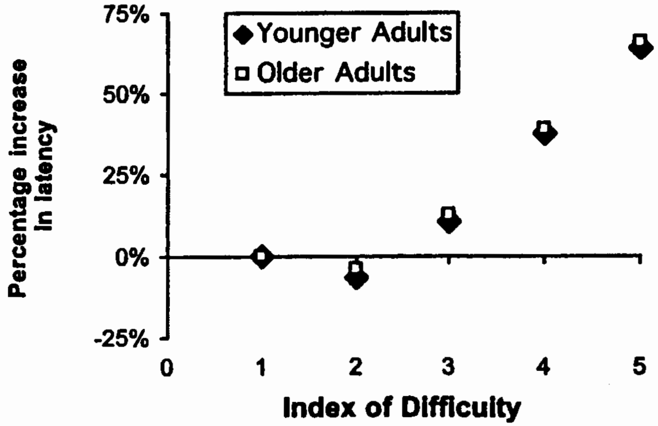

Figure 4. Percentage change in latencies for real sequential movements.

The similar trends in the groups' percentage increases raises the possibility that the interaction observed results from a scaling issue for the observed ordinal interactions[2] (see Kliegl, Mayr, & Krampe, 1995, for a discussion of this issue). One option is that differences between older and younger adults result not from changes to a specific process, but rather from a more general change (e.g., a general slowing in information processing). To address this question we selected a subset of three older participants matched to individual younger participants who had reacted with the closest, but longer, movement time to the first target size for the

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[2] We are grateful to Steve Keele for pointing out this possibility.

real sequential movements. These subgroups show equivalent base movement times for the largest targets (Target ID1, older mean = 8.7s, younger mean = 8.9s, t(4)=0.80, p>.05). However, a comparison of these two subgroups across all 5 target sizes still showed a marginally significant main effect of group (F(1, 4)=7.82, p=.05, partial η^2 =.66, MSE = 8.07) and group by target size interaction (F(4,16)=2.93, p=.05, partial η^2 =.42, MSE = 3.21; see Figure 5). In contrast to the appearance from the previous, percentage adjusted data that was amalgamated across the groups, these analyses suggest that there is at least one specific process in the production of real sequential movements that is different in older adults.

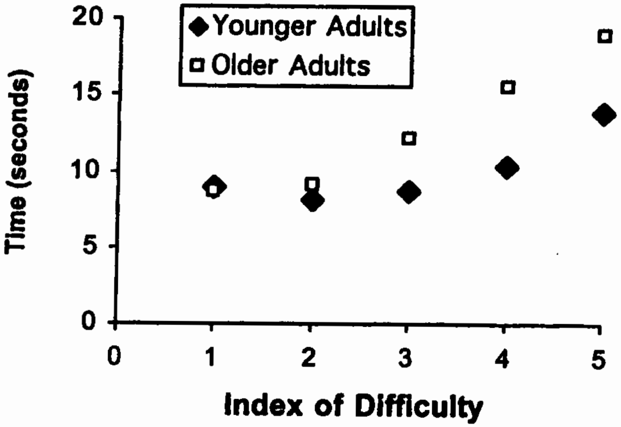

Figure 5. Real sequential movement times for matched subsets of older and younger adults

Finally, additional analyses to maximize power were conducted comparing only the gradients of Fitts' law for each individual, generated from best fit lines plotted through each individual participant's data.[3] For repetitive movement gradients there was a main effect of condition (F(1,26)=25.06, p<.05, partial η^2=.49, MSE=0.031, mean gradient real=0.35, imagined=0.12), but no main effect of group (F(1,26)=2.02, p>.05, partial η^2 =.07, MSE= 0.054, mean gradient younger = 0.19, older=0.28), nor a group by condition interaction (F(1,26)<1, partial η^2=.00, mean gradient young real=0.32, old real=0.39, young imagined=0.07, old imagined=0.17). For sequential movement gradients there was a main effect of condition (F(1,26)=84.89, p<.05, partial η^2 =.77, MSE= 0.34, mean gradient real=1.75, imagined=0.31), no main effect of group (F(1,26)=2.53, p=.12, partial η^2=.09, MSE=0.88, mean gradient younger =0.83, older=1.23), and a significant group by condition interaction (F(1,26)=5.00, p<.05, partial η^2=.16, mean gradient young real=1.37, old real=2.12, young imagined=0.28, old imagined=0.33). These additional analyses mirror the previous findings, supporting the suggestion that the rate of increase in movement time with increased movement difficulty is impacted by age only for the real sequential movements.

Discussion

The critical question this study aimed to explore was whether imagined movements show the same type of age-related decline as real, physically executed movements. As in previous research, the results demonstrate that both real and imagined movements conform to Fitts' law. Both the existing repetitive tapping task and our novel sequential tapping task seem to simulate the characteristics of real movements when imagined motor actions are performed. The adherence of the data to Fitts' law for imagined conditions suggests that participants did imagine the motor movements. The new sequential task extends existing knowledge of imagined movements to the performance of an integrated series of discrete movements, thus extending previous methodology that investigated only multiple repetitions of an identical back and forth movement.

Consistent with previous literature we do find age-related changes in movement times. However, these new data uniquely implicate a specific deficit in the physical execution of the discrete series of actions. Although imagined movement latencies also increased somewhat in the older adults, there was an apparent absence of an age-related effect of difficulty for imagined motor actions. More difficult imagined movements showed no additional decrement, which suggests that aspects of the task not related to the movement components underlie the changes. One plausible explanation is that for imagined movements only a general slowing with increased age was observed. In contrast the results indicate that sequential performance of motor actions became increasingly slower as the difficulty of the movement increased. Since this pattern was not observed for imagined movements, it reduces the likelihood that explanations based on facets of the task such as visual perception of the targets or the non-motoric cognitive components that are common to both conditions could underlie the age-related changes. Although we do not wish to emphasize a null result, the absence of a similar pattern in simpler

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[3] Analyses conducted for gradients of lines through only the four smalles targets sizes also produced the same pattern of results.

repetitive movements, and the fact that differences were greatest for the slowest movements (to the smallest targets), would also tend to imply that the data observed did not result purely from an inability to perform any rapid hand movements.

The systematic progression through decreasing target sizes raises the possibility that order effects rather than movement-based changes caused the older adults' impaired performance. Such an account might seek to explain the changes in terms of some aspect such as fatigue effects or practice effects. Indeed, more generally Hochman (2002) notes that within image variations can occur as experimental conditions change (for example, in the current study as the motoric requirements of the conditions change). As the target size decreased, the images generated by the participants could become less vivid. This would offer one reason why performance became impaired as target size decreased. However, critically, latencies do not just show random interactions with movement difficulty. Regardless of the conditions, all participants continued to demonstrate performance that corresponded to Fitts' law. Therefore, any account based on a time-on-task basis seems unlikely to present a parsimonious explanation for how such changes could continue to produce logarithmic functions. It is not simply that older adults' performance is in some sense slower, but that the changes nonetheless retain the systematic relationship between movement time and movement difficulty observed with Fitts' law. This enormously constrains any possible explanation of these effects, and existing theories of practice and fatigue do not fit with such logarithmic data.

One obvious question that arises concerns the absence of an effect for real repetitive movements. As discussed above, a variety of studies have identified changes in Fitts' law performance with increasing age (Goggin & Meeuwsen, 1992; Welford, Norris & Shock, 1969; York & Biederman, 1991). While many of these studies replicate the single target situation of the repetitive movement task, there are a number of differences between the current situation and previous work that might explain the contrast. One change is from typical use of single movements to a target to the current design that required multiple back and forth movements to a constantly visible target. Recent work suggests there is a difference between the mechanisms used to control cyclic and discrete movements (Smits-Engelsman, Van Galen, & Duysens, 2002). Thus, making a series of identical, reciprocal movements uses different neurophysiological mechanisms than carrying out discrete movements, and our results would imply that these systems remain intact in older adults, allowing them to perform in a fashion consistent with younger adults' performance.

While our results offer some new information on how older adults may differ in psychomotor performance, they do not entirely resolve the issue of why they differ. Whatever the mechanism, it would need to account for the greater impact on performance of older adults for the real, sequential movements. If the findings of preserved imagined movements in older adults can be replicated, then this has the potential to provide an important constraint on interpreting deficits in real movement execution. Brain imaging studies would imply the basis for age-related changes is unlikely to be found in a number of systems involved in the execution of movements, which consistently show activation during imagined movements, including premotor and supplementary motor areas, and the cerebellum (e.g., Gerardin et al., 2000; for a review see Jeannerod, 2001).

Furthermore, while explanations involving peripheral components of processing, such as rate of information transmission (see Salthouse, 1985), might account for uniform decreases in performance, they do not immediately seem to predict a different interaction with target size for one particular combination of movement type and condition. Older and younger adults seem to compose individual movements, as required in the repetitive condition, similarly. However, given that the impact is seen on real, but not imagined, sequential movements, it does seem plausible that this age-related difference results from the type of output transmission rate deficit that Salthouse proposed. Such an account suggests that a slower rate of transmission from the brain to the muscles exists within older adults, but an explanation of how this would interact with movement difficulty is still required. One possibility is that information transmission rate is especially critical in the submovements used to hone in on a target. Consistent with this idea previous research suggests that more movement adjustments occur for older adults (e.g., Goggin & Meeuwsen, 1992), but that submovements are not always present for easier targets (Liao et al., 1997).

Other research suggests that when switching to the sequential condition, strategic differences may exist (see, for example, Liao et al., 1997). One possible explanation for this is that older adults switch in the sequential condition to performing movements individually using closed-loop control rather than planning sequences using open-loop control. For example, Rabbitt (1982) suggested that in controlling movements older adults lose the use of predictive mechanisms and are forced to rely on reactive mechanisms. One way to account for the difference between real and imagined movements in the sequential conditions would be in terms of the change in (visual/proprioceptive/kinesthetic) feedback available. Under the real movement conditions, feedback allows older adults to implement individual, closed-loop movements. However, in the imagined movement condition, no feedback is present and, therefore, such a closed-loop strategy confers no obvious advantages.

It has been suggested that imagined movements have a functional equivalence to motor preparation for physical movements (Jeannerod, 1994). Thus, one source for the distinction between real and imagined movements could relate to a contrast between planning plus executing a movement versus planning plus mentally simulating the movement. The results overall suggest that with increased age imagined movements may suffer less of a decrement than physically executing movements. Since in this view planning components are common to real and imagined movements, poor performance with changes of target size on sequential, real movements alone would imply an execution problem for older adults independent from planning deficits. The relatively intact performance of older adults on the imagined, sequential movements raises the possibility that the motor preparation system remains able to function in a predictive fashion, but that such a mode of performance does not operate when actual execution is involved. These issues seem worth further investigation.

One suggestion as to the purpose or function of imagery is that it "facilitates access to the real" (Hochman, 2002, p. 131). According to such accounts, the principle purpose of mental imagery is not recall of previous events but rather as a form of enactment (see, Ahsen, 1984, 2001). Along these lines, one potential implication of our findings relates to skill learning, and in particular learning the sequences of actions that might typically be required. Utilization of imagined performance of a skill might allow older adults to bypass elements of performance that would otherwise be more impacted by their age. Hence in terms of aspects like integration of motor programs in learning certain skills (where timing of elements may prove critical), one prediction is that for older adults mental practice could offer benefits compared to physical practice. However, note that Willingham (1998) argues that mental practice need not utilize all the same processes as physical practice, and this may impose limits on potential benefits (see also Dagnall, 2002, for factors affecting the utility of mental practice). In light of this, possible practical implication for our findings, a study by Jarus and Ratzon (2000) offers some interesting data on physical versus mental practice of a bimanual tracking task. Their findings show that relative to younger adults who perform equally well following mental or physical practice, older adults perform significantly better following mental practice than physical practice. Our results offer one potential explanation of this finding, and suggest that the benefits of mental practice for older adults are certainly worth future investigation.

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Correlation of EEG Activity with Subjective Performance on a Guided Imagery Test: An Exploratory Study

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The purpose of this study is to advance a neurocognitive investigation of clinical techniques that rely on the manipulation of the patient's imagination, such as guided imagery and therapeutic hypnosis, within the context of a more encompassing theory of imaged experience or "imaginoception." The pilot study investigated the potential relationship between reported vividness of imagery during a guided imagery task (including visual, olfactory, auditory, tactile and motor imagery), and activity in the electroencephalograph (EEG) power spectra, specifically in the theta band. EEG was recorded from 18 subjects during three intervals: a 3-minute pre-task interval, a 3-minute guided imagery interval (i.e., the "task" interval), and a 3-minute post-task interval. Results show very high correlations between vividness of imagery and levels of frontal midline (Fm) theta power in both the 3-minute pre-task ($R = 0.8857$) and task ($R = 0.8837$) intervals, and with total theta power (sum of theta power recorded in 15 channels) ($R = 0.9257$ and $R = 0.8334$, respectively). These results may indicate that the neural mechanisms associated with the production of Fm-theta in particular, and theta rhythms in general, play a role in the creation of vivid dynamic imagery. Furthermore, they may be suggestive of general cerebral processes related to the production of imaginoception.

Narrowly defined, the present study is concerned with the neurobiological trends, as measured by levels of Fm-theta in the EEG, that may correlate with the subjective vividness of an experience during a guided imagery task. The underlying premise is that the neural mechanisms responsible for the creation of Fm-theta may also contribute to the creation of vivid mental images; that is, Fm-theta may be a surface manifestation of the mechanisms associated with the production of vivid mental

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