DEVELOPMENT OF CONSTRAINED MOVEMENTS
IN THE FIELD SETTING

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INTRODUCTION

Cognitive psychologists, through the ages, have been baffled by how the brain fulfils its function as the executive of life, controlling all intentional actions. The brain is the repository of memory, constantly interacting with stimuli from the environment in order to make stored information current. Human memory is not static but dynamic, constantly updating knowledge for future reference, providing as it does an improved base for human performance. The brain is also the centre for sensation, interpreting both sensory inputs and actions in light of its current goals. However, despite its undisputed role as the seat of knowledge and learning, understanding of the functioning of the brain, especially with respect to memory, is still only in its infancy. Nevertheless, progress is apparent and more has been learned, in the last twenty years, about memory than in all the years beforehand.

Memory for movement is an important element of general human memory. Motor memory, as it is commonly labelled, is critical for the acquisition of all movement skills. Memory for movement, particularly short-term memory (STM), is vital for the learning and integration of all day-to-day human activity, especially in the acquisition of new skills.

THE OBJECTIVES

The main aim of this experiment is to assess the assumptions made by authors of motor learning texts that the principles of motor STM derived from the laboratory study are directly applicable to the learning of "real-world" skills. The other purpose is to ascertain if the developmental trend is present. The experiment was formulated to ascertain whether the current motor STM principles derived from contrived laboratory tasks are indeed indicative of the operations of STM in the natural setting and not merely artifacts of the laboratory methods and to ascertain the nature of any developmental differences in motor STM usage.

The Theory-Practice Link in Motor STM Research

Authors of a number of motor skill acquisition books (e.g., Magill, 1989; Marteniuk, 1976; Sage, 1984), have drawn implications directly from the existing laboratory-based motor STM research on adults to practical teaching/learning situations involving not only adults but also children. The assumptions made, in such a case, are (a) that children learn motor skills and encode information into motor STM and generally use STM in the same way as adults and that (b) regardless of the age of the subjects, the laboratory findings are directly applicable to the practical, field setting. Criticism of such assumptions has also been made by Gallagher and
Thomas (1986) and Schmidt (1988). The direct applicability of laboratory-bound principles on studies of adults to children learning motor skills in the field setting will be examined.

Gentile (1972) in attempting to formulate "A Working Model Of Skill Acquisition With Application To Teaching", found that motor STM, like the other areas of motor learning, was lacking in unifying themes. Similarly, Fischman, Christina and Vercruyssen (1982) reviewed as many as ten textbooks on motor learning, mainly published in the 1970s, in an attempt to present the scientific concepts of areas of retention and transfer to the practitioners. They found, like Gentile (1972) a decade before them, that there were "many inductive leaps and intuitive jumps from data to general statements" (p. 3) that had to be made in order to derive motor STM principles of use to the practitioner. The extent of these "leaps" and "jumps" needed from laboratory research to field application limit, substantially, the practical value of the majority of motor STM research conducted thus far. Experimenters, to date, have approached motor STM research in a piecemeal fashion (Marteniuk, 1976), using as movement tasks novel forms of movement which bear such little relevance to "real-world" actions that they may be largely considered trivial (Thomas, French & Humphries, 1986). These problems, which limit the generation of knowledge of value to practitioners concerned with the acquisition and recall of motor skills will be discussed.

Problems with the Existing Motor STM Knowledge Base

The Problem of Ecological Validity

The applicability of research to "real-world" or natural settings is frequently referred to as ecological validity (after Neisser, 1976). The call for research to be ecologically valid has been made by research leaders in a number of fields of study (e.g., Jenkins, 1974; Neisser, 1976) with the collective emphasis being upon the need for research "relevance". This call for relevance was first made by the social psychologists in the mid-1970s (e.g., Argyris, 1975; Bronfenbrenner, 1974, 1977; Jenkins, 1974; McCall, 1977). In cognitive psychology, Neisser (1976, 1978), in particular, pointed out that most psychological studies of cognition and information processing were conducted in the laboratory setting and therefore, lack ecological validity because they examined situations that did not accurately reproduce the "real-world" setting for which understanding was sought. As a result, Neisser presented an alternative approach in his 1976 book, "Cognition and Reality", which stressed the need for a more ecological orientation for cognitive psychology.

In the area of motor learning and sport psychology, Martens (1979), who did an introspective analysis of his own work, was among the first to query the direction of laboratory research. He questioned the apparent gulf between the laboratory research which predominated in motor learning and in sport psychology and the natural world it was ultimately attempting to explain. He called for a new or modified paradigm for motor learning and sport psychology research with less contrived settings and more applied field research. At the same time, Gibbs (1979), in his review of ecological validity in psychological research, also questioned the extreme approach where researchers divorced the experimental stimuli from the subject's ordinary experience. McCall (1977) expressed the opinion that researchers had not taken the time necessary to make systematic studies in the naturalistic settings, to observe the identified
behaviour before venturing into controlled laboratory research. Likewise in the developmental field, Bronfenbrenner (1977) described developmental psychology as "the science of the strange behaviour of children in strange situations with strange adults for the briefest possible periods of time" (p. 513), and this comment appears to bear particular relevance to this experiment with its focus upon school-aged learners.

Although a shift in focus is necessary to prevent "the pursuit of certainty to the detriment of authenticity" (Gibbs, 1979, p. 127), a balance in the two approaches is vital (Martens, 1987). Most will agree that both settings, the laboratory and the field, can contribute immensely to inductive and deductive reasoning and can lead to the better understanding of human behaviour.

The call for "relevance" over "rigour" has been made within the context that cognitive psychology has over-emphasised the studies of human behaviour within the laboratory-bound approach. The underlying message must be to correct the lop-sided laboratory-dominated trend to a more balanced and integrated approach (Baddeley, 1984; Bronfenbrenner, 1974, 1977; Martens, 1979; Thomas, French et al., 1986). There is a clear need to recognise that both natural (field) and laboratory methods have their limitations and both possess distinctive merits as well (Martens, 1987). Field methods direct answers to specific questions on whether and how principles of human behaviour operate in the context of reality. The laboratory approach provided the condition for separating and controlling the variables for isolated study that leads to the building of theoretical concepts. Baddeley's (1984) argument for the establishment of a durable bridge between memory research in the laboratory and memory studies in everyday life is critical, and seems particularly true for the study of STM for movement.

To summarise, both laboratory and field approaches are useful in the pursuit of knowledge. The respective strengths and weaknesses of the two approaches argue against the exclusive use of either. Instead, laboratory and field research should attempt to converge on common principles to permit a variety of useful integrated designs each with their own combination of naturalism and control (Weisz, 1978). The historical dominance of laboratory over field research in motor STM argues clearly for the need for natural ecologically valid examinations of memory for movement, to redress the current imbalance.

The Problem of Population Specificity

A second major problem which hampers attempts to draw useful teaching-learning implications from existing motor STM research is the dearth of studies on subject populations other than adults. Most authors of texts on motor skill have tended to draw conclusions and applications from the laboratory situations on adults directly to children. There are obvious developmental differences between adults and children and such convenient assumptions that children behave like adults with respect to motor STM problems should be treated with extreme caution. Just as laboratory studies may not be appropriate for field understanding; likewise, applying concepts from the study of adults to the study of children may be equally, if not more, inappropriate.

There are only a few studies on children in the motor STM and as a consequence, much of the limited knowledge is borrowed from the verbal STM literature (Laabs, 1981).
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limited motor STM studies are mainly on the use of mnemonic strategies and relative retention characteristics for the recall of movement. The privileged motor STM topics such as distance versus location, preselected versus constrained movement recall and inter-sensory integration evident in adult work have been the focus of very little developmental research. The scant evidence suggests that lack of spontaneous use of control processing by younger children (e.g., Sudgen, 1980; Thomas, Thomas et al., 1983), resulting from the ineffective use of strategy, rather than capacity differences, is the principal basis of age-related differences in recall performance (e.g., Chi, 1976; Gällagher & Thomas, 1984; Thomas, 1980).

Collectively, the limitations imposed by the predominant use of laboratory studies and the lack of studies on school-aged children make it difficult to obtain knowledge from the existing motor STM literature which can be easily applied by practitioners to the teaching and learning of motor skills by children.

THE EXPERIMENT

Although distance and location cues have been examined extensively in the laboratory setting, there has been very little attempt at determining whether these effects hold in more naturalistic (field) settings. The only known study in this area was by Thomas, Thomas et al. (1983).

Thomas, Thomas et al. (1983) used 5-, 9- and 12-year-old children to test the encoding of distance and location cues in a field setting. Each child jogged with an experimenter and at a designated place, the experimenter paused to remove a rock from his shoe. The point at which this event occurred indicated the extent covered or location to be reproduced. The subject was then led back to the starting position in a semi-circular path to avoid covering the same extent again. The subject was cued what to remember prior to each jog. From the starting position, if location was to be remembered for the trial, the subject was told to identify the exact spot where the event occurred. For testing of the distance covered, the child jogged along a straight line perpendicular to the original course for a distance equivalent to that covered in encountering the original event. A string was laid to help the subject to walk or jog in a straight line. Although Thomas, Thomas et al. (1983) found that the recall of location cues were more accurate than distance cues, a comparison between the results of this field experiment with the laboratory studies is not possible as their subjects had visual information.

In this study, a similar field-based approach was taken, except that the experimental design used was a more direct analogue of the typical laboratory paradigm for examining distance and location. Subjects were denied vision and the RSPs were systematically varied to facilitate the subject’s reliance on one movement cue at a time.

The purpose of this experiment therefore, was to ascertain whether the movement cue and movement length effects and the mutual interaction of distance and location cues, as observed in the constrained laboratory setting (Quek, Exp 1), would also emerge in a more naturalistic field setting where subjects were required to make whole body movements rather than limb movements. This comparison was also extended to an examination of whether age
differences in movement recall in the field mirror the findings from the laboratory test. In addition, the results of this experiment would permit a comparison of the limb movements (laboratory) with gross movements (field) to determine whether the distance-location interaction arises as a consequence of specific receptor characteristics in the limbs or a result of more general cognitive factors.

In keeping with Thomas, Thomas et al.'s. (1983) results, it was predicted that the 18-year-old subjects would recall movements with greater accuracy than the other age groups and that movements using location cues would be reproduced more accurately than distance. No a priori hypotheses were made for respective use of the different movement cues as a function of movement length or for the mutual interaction of movement cues as no previous studies have been conducted.

METHOD

Subjects

The same 100 male subjects involved in the laboratory (Quek, 1990) were used. There were 20 subjects in each of the age levels: 6, 9, 12, 15 and 18 years. The order of testing the laboratory and field experiments was counterbalanced; therefore half of the subjects participated in laboratory experiment first and the other half in the field experiment.

Apparatus

A rope of 30 m in length was suspended horizontally at a height of approximately 90 cm above the ground using metal uprights as props. The rope was used as a guide for the blindfolded subjects to move in the right direction. The measuring tape was laid on the ground directly below the rope. The test took place within a school auditorium.

Procedure

To prevent the subjects from drawing visual cues from the layout of the experiment, they were blindfolded in a room before being led to the auditorium. After preliminary instructions, the subjects practised walking in a straight line, holding the guide rope with their right hands. This requirement was roughly akin to moving the lever in the laboratory task used in laboratory experiment (Quek, Exp. 1, 1991). Subjects were instructed to remember either the distance or terminal location cue as it was the only source of information available. Each subject had three practice trials before commencing the actual experiment.

For each trial the command, "Ready", was given before the criterion movement (CM), the movement to be remembered, was presented. The experimenter followed the subject and helped him with the last stride to ensure that his final stride took him to the desired finishing position. The subject then turned around and walked back, also with the aid of the rope, to the original starting position. A retention interval of 15 s was used, as in the laboratory task, and then reproduction movements (RMs), the recalled movements, were made from recall starting positions (RSPs).

RESULTS AND DISCUSSION

As the results are about 97% for the young subjects, only selected effects will be discussed as the overall experimental results are shown in Table 1.

Age as the Main Factor

Significant differences were found with respect to the comparison of the long movement with the young.
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positions (RSPs) of either +1.5 m, 0 m or -1.5 m. (The RSP value was adopted to maintain the ratio of about 1:3 between the RSP and the short movement and 1:14 between the RSP and the long movement, as in laboratory experiment.) When the subject thought that he was at the correct location or distance in the RM, he was required to indicate to the experimenter the precise spot (or terminal location) with the pointed end of his right shoe. The extent moved was recorded to the nearest centimetres. The intertrial interval was 20 s. After the experiment, the subject was interviewed regarding the strategies he had used for the movement reproduction. The break for the interview and the recess between the testing of the distance and location cues were in the order of 2 - 5 minutes.

Experimental Design and Analysis of Data

The design and analysis of data of this experiment is similar to that in Experiment 1. The factorial design was a 5 x 2 x 2 x 3 (Age x Movement Cue x Movement Length x Recall Starting Position) with the first factor being a between-group factor.

The extent of the CMs selected for use in this study were 5 m and 23 m. (These distances are about 97% longer than the short and long movements used in laboratory [Quek, Exp. 1, 1991].) They are equivalent to the short and medium ranges of Thomas, Thomas et al.'s. (1983) experiment. In total, three RMs were made at each of the RSP x Movement Length combinations. The order of presentation of these combinations were randomised while the order of testing the location and distance conditions were counterbalanced.

Four-way ANOVAs with repeated measures were applied to the dependent measures of AE, CE, VE, |CE| and E. However, only the first three measures would be reported and discussed as they are the common measures reported in other similar research. Tukey post-hoc tests were then used to evaluate the source of significant effects. Statistical significance for the overall experiment was at the 0.05 alpha level and Bonferroni criterion was at 0.003%.

RESULTS AND DISCUSSION

As the results of the analyses of the five measures of error are tabled in Appendix A, only selected effects of the three main error scores are reported and discussed.

Age as the Main Effect

Significant main effects for age were evident for all the three measures of error, AE, \( F(4, 1191) = 86.135, p < .0001 \); CE, \( F(4, 1191) = 13.136, p < .0001 \) and VE, \( F(4, 1191) = 71.968, p < .0001 \). The mean error scores and standard deviations of the various age groups are shown in Table 1.

For AE the comparisons between all the adjacent age groups were significant except for the comparisons between 15- and 18-year-olds. Analyses of CE and VE also revealed similar trends. All three error scores indicate a definite developmental trend for movement reproduction with the youngest age group recording the highest error scores and variability and with both the
accuracy and variability improving with age (Figure 1). Although it was predicted that the oldest age group would be best at the movement reproduction task the absence of significant differences between the 15- and 18-year-olds was not unexpected as both groups are believed to be capable of organising and executing appropriate cognitive strategies (Gallagher & Thomas, 1984, 1986).

Table 1: Mean Error Scores (m) as a function of Age

<table>
<thead>
<tr>
<th>Dependent Measures</th>
<th>AGE (Year)</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>6</td>
<td>9</td>
<td>12</td>
<td>15</td>
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<tr>
<td>AE m</td>
<td>1.802</td>
<td>1.312</td>
<td>0.996</td>
<td>0.630</td>
<td>0.621</td>
</tr>
<tr>
<td>SD</td>
<td>1.052</td>
<td>1.123</td>
<td>0.955</td>
<td>0.614</td>
<td>0.474</td>
</tr>
<tr>
<td>CE m</td>
<td>0.761</td>
<td>0.257</td>
<td>0.064</td>
<td>0.146</td>
<td>0.231</td>
</tr>
<tr>
<td>SD</td>
<td>1.691</td>
<td>1.509</td>
<td>1.295</td>
<td>0.766</td>
<td>0.636</td>
</tr>
<tr>
<td>VE m</td>
<td>2.025</td>
<td>1.499</td>
<td>1.162</td>
<td>0.708</td>
<td>0.714</td>
</tr>
<tr>
<td>SD</td>
<td>1.185</td>
<td>1.379</td>
<td>1.265</td>
<td>0.683</td>
<td>0.547</td>
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Movement (see Figure 1)
predicted that the influence of significant groups are believed (Lagier & Thomas).

Likewise, the inaccuracy and variability of scores for the youngest group may well be due to very few of the 6-year-olds spontaneously adopted strategies for recall (e.g., Sugden, 1980; Thomas, Thomas et al., 1983; Winther & Thomas, 1981). For the 9- and 12-year-olds, their inaccurate movement reproduction could be a result, not of their non-use of strategies but their inefficiency in planning and executing strategies (Gallagher & Thomas, 1984, 1986).

Movement Cue Effects

AE and VE scores were significantly influenced by the movement cue used for reproduction, $F(1, 1191) = 17.622, p < .0001$ and $F(1, 1191) = 11.527, p < .0001$, respectively. Location was recalled significantly more accurately and less variably than distance—a result consistent with the field experiment of Thomas, Thomas et al., (1983) and with laboratory experiment (Quek, Exp. 1, 1990). None of the error measures of were significantly mediated by age with no significant age interaction with movement cue (AE, $F(4, 1195) = 1.658, p < .157$ and VE, $F(4, 1195) = 0.751, p < .557$). Like in laboratory experiment, therefore age does not seem to mediate as a factor in the use of movement cues. This could be due to the use of cognitive strategies which narrowed the differences between the age groups in their RMs.

Movement Length Effects

Movement length effects were significant for all three error scores, AE, $F(1, 1191) = 62.566, p < .0001$; CE, $F(1, 1191) = 36.698, p < .0001$ and VE, $F(1, 1191) = 54.384, p < .0001$. Although short movements were recalled more accurately and less variably than the long movements, as noted in laboratory experiment (Quek, Exp. 1, 1990), discretion must be exercised with regard to such a conclusion. Due to the relative definition of the length of short and long movements and the lack of a common denominator between them, the comparison of accuracy of recall based on movement length may be erroneous.

![Figure 2: Mean Constant Error as functions of Age and Movement Length in Experiment 2.](image-url)
The range effect, which describes the tendency to overshoot short movements and undershoot long movements, was only partially evident in this field experiment. The central tendency effect (Laabs & Simmons, 1980; Pepper & Herman, 1970) was evident for the short movements but the mean error CE for the long movements (0.088), although close to the zero mark, did not systematically undershoot like the long movements executed within the laboratory setting.

A significant Age x Movement Length interaction was obtained for CE, \( F(4, 1140) = 13.980, p < .0001 \) but not for AE, \( F(4, 1140) = 0.655, p < .622 \) and VE, \( F(4, 1140) = 0.619, p < .649 \). Response bias differences were evident for movement length for the 6-year-olds but not for the other groups (Figure 2). The data revealed that for the younger age groups, short movements overshot more than long movements; whereas no response bias was evident for the 15- and 18-year-olds.

The effects of Movement Length x Movement Cue on recall accuracy of movement was not significant \( [AE, F(1, 1198) = 0.813, p < .367]; CE, F(1, 1198) = 0.502, p < .479] \). This result is contrary to that of laboratory experiment (Quek, Exp. 1, 1990). Possibly, the critical difference of movement range in defining the short (5 m) and long movements (23 m) in a large environment has not been met. In all probability, the processes involved in the encoding of both movement lengths were similar and this resulted in the obscured nonsignificance of the Movement Cue x Movement Length analysis.

**Recall Starting Position Effect**

RSP changes had a main effect upon all three measures of error, AE, \( F(2, 1191) = 34.342, p < .0001 \); CE, \( F(2, 1191) = 69.274, p < .0001 \) and VE, \( F(2, 1191) = 23.548, p < .0001 \). The analysis of CE scores revealed that the responses made at the three RSPs were significantly different. The data showed over- and under-shooting in the recall of movements. The Age x RSP interaction was also significant \( [CE, F(8, 1140) = 3.497, p < .001; AE, F(8, 1140) = 3.442, p < .001] \). The interaction, which also resulted in the similar over- and under-estimation in the responses, affected the younger age groups more than the older age groups (Figure 3). The RMs were overestimated when the RSPs were moved away from the terminal locations of the CMs (-1.5 m) and the reverse (underestimation) occurred when the RSPs were moved closer to the terminal locations (+1.5 m). This same systematic directional bias was also observed in the laboratory experiment although, consideration of the Movement Cue x RSP interaction reveals more on the response bias effects due to the use of specific movement cues.

Significant Movement Cue x RSP interaction was evident only for CE, \( F(2, 1197) = 24.341, p < .0001 \). Significant differences in CE were evident for distance cues at each of the RSPs and also between recall based on distance and location cues at RSP -1.5 m (Figure 4). There was not significant effects at all due to the use of location cues and neither were the distance and location cues at RSPs +1.5 m and 0 m significantly different. The RSP at 0 m, which had both distance and location cues and which acted as a control revealed, as expected, no significant CE differences between the distance and location conditions.
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Figure 3. Mean Constant Error as functions of Age and Recall Starting Position in Experiment 2.

Figure 4. Mean Constant Error as functions of Movement Cue and Recall Starting Position in Experiment 2.
In the field setting therefore response bias was apparent for RMs using distance cues but not for those using location cues. When the RSPs were moved closer to the terminal locations of the CMs (+1.5 m), the recalled responses using location were not influenced by distance cues, but were as accurate as the RMs made at the original starting position (where both distance and location were used). For the RMs at RSP -1.5 m, location was again not subjected to the influence of distance cues otherwise it would have undershot. On the other hand, the recall of the distance movements was under the influence of location cues, as evident by the systematic over- and under-estimation of the RMs. These results therefore partially support the integration hypothesis (Walsh et al., 1979, 1980, 1981) with distance cues being influenced by location cues but not the reverse. Location, which is possibly centrally represented (Geron, 1986; Kelso, 1977; Laabs, 1973), is apparently more stable and resistant to bias effects than distance cues.

Age exerts a mediating influence upon the Movement Cue x RSP interaction for CE, \[ F(8, 1170) = 4.212, p < .0001 \]. Location appears to be the dominant cue for movement recall in the field setting exerting its influence on distance for all the age groups tested (Figure 5 a, b, c, d, e). Except for the 6-year-olds (Figure 5a) who overshot with location movements when the RSPs were moved closer to the terminal locations of the CMs (+1.5 m), the distance did not reciprocate its influence on location for the other age groups. In fact, the movements using distance and location cues seemed to produce similar bias when the RSPs were shifted to the left or right of the initial locations of the CMs. Although the differences in response bias for movement location between the 6-year-olds and the other age groups is not fully understood, the data seemed to indicate that the subjects adopted similar strategies for the recall of location and distance movements.
In the recall of movements in a large environment which required the subjects to remember movements beyond the length of the limbs, the subjects had to rely on a series of movements using stride length and paces to ascertain the extent. It seemed difficult for the subjects not to depend on both pacing (location) and stride length (distance) for the entire extent. Assuming that the separation of cues was possible, the movements using distance cues seemed to exhibit the response bias in the direction of the terminal locations for all the age groups as in the laboratory experiment. This asymmetrical influence of the cues seems to partially support the integration hypothesis as postulated by Walsh et al., (1979, 1980, 1981). However, it also possibly indicates that the present experimental paradigm to analysis either distance or location cues inherent in the movement is perhaps difficult, if not impossible.
Interview Data on Response Strategy

Two main points were evident in the interviews conducted after the experiment. The details of the interview are tabulated in Appendix B. Firstly, very few of the 6-year-olds (21.90%) employed counting strategies for recall compared to 92.50% of the 12-year-olds and 91.09% of the 18-year-olds. Fifty-six percent of the 6-year-olds did nothing or could not identify the cues used to aid them in their recall; whereas all of the subjects in the 12 and 18 age groups reported employing some type of strategy (Figure 6).

Secondly, the strong reliance on counting and cognitive strategies appears to be a feature peculiar to the field experiment. In the laboratory study (Quek, Exp. 1, 1990) kinesthesis, visualisation, timing as well as counting, were the main strategies used. However, for this field study, the average of the three main age groups identified for discussion (6-, 12- and 18-year-olds) showed only 3.86% of all the subjects relied on kinesthesis but 68.49% employed counting strategy. In addition, 8.89% of them used cognitive strategy in adding and subtracting the extent because of the varied RSPs.

In sum, the different experimental setting has brought about an adaptation in the use of strategies and cues for the recall of movements. For movements that are exocentric (i.e., outside the body-related sphere) and involve a series of bi-pedal movement, counting seemed to be the main strategy employed for the recall of movements. Such a strategy was rarely reported for the laboratory experiment.

Figure 6. Percentage as a function of Movement Cue (Interview Data) in Experiment 2.

GENERAL

This study was different from traditional research designs in the gross movement paradigm. It emerged as a significant area of research previously not considered. In its superior investigated gross movements did not seem to work for 23 m, probably for the reasons:

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CONCLUSION

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GENERAL DISCUSSION

This experiment was designed to examine the applicability of the established findings from traditional motor STM to the context of motor recall by school-aged subjects performing gross movements in a field setting. In general, the same basic motor STM effects seem to emerge as a function of age in an ecologically more valid field experiment as have been previously reported from the controlled laboratory experiment. Location, unequivocally exerted its superiority over distance in movement recall. Movement length and movement cue effects did not seem to be a factor in the recall accuracy of movements as both movement extents, 5 m and 23 m, probably are not within the discriminating range of a "short" and "long" movement.

On the issue of the mutual interaction of distance and location cues, the directional bias effects systematically induced by changes in RSP in the laboratory was only evident in the field setting for movements using distance cues. This indicates that terminal location is a more powerful influence on distance recall than distance is on location recall. However, the trend of over- and under-estimation of location responses mirror those of distance recall. This atypical finding on location could be the result of the adoption of similar strategies for movement recall as used for the recall of distance. The results suggest that the coding of location in the field setting is difficult without the use of vision. In a large environment, vision undoubtedly facilitates the allocentric system (the use of environmental cues).

CONCLUSIONS

The results of these two experiments on school-aged subjects confirm that the existing findings on motor STM are robust ones holding quite generally to use of movement cues for constrained movements for both children of different ages and for gross field based movements as well as constrained single-limb movements in the laboratory. The same principles of motor STM with respect to the effects of movement cue, movement length and movement cue upon recall accuracy, and the mutual interaction of distance and location cues reported in the studies of adults emerged clearly for the school-aged subjects tested in the laboratory setting. In the field setting, the main effects of movement cue and the asymmetrical influence of distance-location cues were again evident although the differential effects of the distance and location cues upon the recall accuracy of movements of different length was not replicated. This nonsignificance and the asymmetrical influence of movement cues clearly need further investigation for gross movements performed in the field setting.

The main effect of age was recorded in both experimental settings. Similar to other developmental studies in the laboratory (e.g., Collins, 1976; Gallagher & Thomas, 1986; Thomas, 1980; Winther & Thomas, 1981) and the only field study to date (Thomas, Thomas et al., 1983), age was directly related to the absolute accuracy and consistency of the recalled movements. The age effect was more pronounced in the field than the laboratory setting however. While the large environment study could have magnified the differences between the variables due to the use of larger movement lengths, it is also possible that the field experiment was more sensitive in detecting the developmental differences between the age groups. The field
Task also has more degrees of freedom than the simple uniplanar movement used in the laboratory and therefore has more potential components that can improve over time. In both settings however, the RMs of the 15- and 18-year-olds were not significantly different. Probably, this suggests that adult-levels of performance are attained around the age of 15. Both age groups seemed to use multiple and more complex strategies to aid them in their recall than any of the younger groups. The younger subjects relied, generally, on one source of information or utilized only one, or in many cases, strategy. They possibly, also lacked efficiency in the execution of any strategies they adopted (Gallagher & Thomas, 1984).

Location was the dominant cue for movements recalled in both the laboratory and field settings. Its advantage in spatial orientation within the laboratory context had been attributed to the availability of body-related reference points (Wrisberg & Winter, 1985), variously referred to as the egocentric system (Pick, 1970; Rieser & Pick, 1976) and as an integral component of the target hypothesis (Buck, 1982; MacNeilage, 1970; Russell, 1976; Wallace, 1977). It may well have been that a spatial location code fixed with reference to the body and used by the subjects in the laboratory experiment. However, in the context of the field experiment where the movement lengths were exocentric (i.e., beyond the body reference points), the only way to encode location cues was by replicating the width (or pace) of a series of specific stride. However, each stride consists of an extent of a specific length, which is basically a distance cue in nature. It is difficult to envisage that the subjects could distinguish the difference between the two, especially when they were not cued to employ such strategies. Therefore in the RMs in the field, the subjects could have used similar strategies for the recall of both cues and this, possibly, accounts for the absence of any significant age by movement cue interaction in the field setting.

The interaction between distance and location cues referred to by Walsh et al. (1979, 1980, 1981) was evident for all age groups in the laboratory experimental settings and for the youngest group of the field experiment. Although the mutual interference of these two cues was not recorded for all the older age groups in the field study, the movements with distance cues were drawn towards the terminal locations of the CMs. From the over- and under-estimation of the RMs of movement location, it appears that movements using location cues were using the same strategies as movements using distance cues. Another possible way to examine the distance-location cue usage more specifically in the field setting would be to introduce vision as a means of enhancing location cues needed for the gross movement control. Vision, which is vital in the encoding of spatial location (Gupta et al., 1986; Podbros et al., 1981; Smyth & Wing, 1984) employs the allocentric system (i.e., environment-related references, Larish & Stelmach, 1982; Stelmach & Larish, 1980), will be considered in future research.

The effects of the mutual interaction of distance and location cues in the laboratory (involving the movements of an arm) and although partial influence in the field (involving gross movements) seem to indicate that the distance-location interaction is, probably, not a result of kinesthetic disorientation. As the RMs of the both experiments are generally affected, the distance-location interaction could be caused by some cognitive factors and not specific kinesthetic feedback mechanisms. However, the results of two experiments support the assumption that the control processes in motor STM are coded in the same way (Thomas, 1980; Thomas, Thomas et al., 1983), irrespective of whether it is the movement of an arm in the laboratory or oriented, lateral movements.
...used in the time. In both age groups than any of the information or efficiency in the laboratory and field have been attributed to variously referred to as the component of 1977. It may and used by the question where the specific stride is a distance cue...ference between not the RMs...h cues and this, action in the field...

Arish et al. (1979, things and for these two cues was...ith distance cues under-estimation of the two cues was the...to examine the hypothesis that the results of age...s with...s, distance perception as a function of age. Australian Journal of Psychology, 28(2), 109-113.


QUEK


DEVELOPMENT OF CONSTRAINED MOVEMENTS


### Appendix A

**SUMMARY OF STATISTICAL ANALYSIS OF Experiment 2**  
*(FIELD: CONSTRAINED CONDITION)*

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>MEASURES OF ERROR</th>
<th>(SIGNIFICANT LEVEL)*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CE</td>
<td>VE</td>
</tr>
<tr>
<td>Age</td>
<td>0.0001</td>
<td>0.0001</td>
</tr>
<tr>
<td>Movement Cue</td>
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<td>0.001</td>
</tr>
<tr>
<td>Movement Length</td>
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<td>0.0001</td>
</tr>
<tr>
<td>RSP</td>
<td>0.0001</td>
<td>0.0001</td>
</tr>
<tr>
<td>Age x M Cue</td>
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<td>0.395</td>
</tr>
<tr>
<td>Age x M Length</td>
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<td>0.649</td>
</tr>
<tr>
<td>AGE x RSP</td>
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<td>0.001</td>
</tr>
<tr>
<td>M Cue x M Length</td>
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</tr>
<tr>
<td>M Cue x RSP</td>
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</tr>
<tr>
<td>M Length x RSP</td>
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<td>0.020</td>
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<tr>
<td>Age x Cue x Length</td>
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</tr>
<tr>
<td>Age x Length x RSP</td>
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<td>0.030</td>
</tr>
<tr>
<td>Age x Cue x RSP</td>
<td>0.0001</td>
<td>0.096</td>
</tr>
<tr>
<td>Cue x Length x RSP</td>
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<td>0.512</td>
</tr>
<tr>
<td>Age x Cue x Length x RSP</td>
<td>0.392</td>
<td>0.442</td>
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</table>

* OVERALL SIGNIFICANCE: p < .05%;  
  BONFERONNI CRITERION: p < .003%
## EXPERIMENT 2: INTERVIEW DATA
### NUMBER AND PERCENTAGE OF STRATEGY USAGE

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<th>AGE (Years)</th>
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<th>9</th>
<th>12</th>
<th>15</th>
<th>18</th>
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<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
<td>n</td>
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<tr>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>1</td>
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<tr>
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<td>21*</td>
<td>100</td>
<td>20</td>
</tr>
<tr>
<td>LOCATION</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kinesthesia</td>
<td>2</td>
<td>9.52</td>
<td>2</td>
<td>9.09</td>
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<tr>
<td>Counting</td>
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<td>72.72</td>
<td>19</td>
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<tr>
<td>Estimation</td>
<td>3</td>
<td>14.28</td>
<td>1</td>
<td>4.54</td>
<td>1</td>
</tr>
<tr>
<td>No Strategy</td>
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<td>13.63</td>
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<tr>
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<td>21*</td>
<td>100</td>
<td>22*</td>
<td>100</td>
<td>20</td>
</tr>
<tr>
<td>DIST &amp; LOCAT</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kinesthesia</td>
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<td>6.92</td>
<td>2.50</td>
<td>8.01</td>
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<td>92.50</td>
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<td>5.00</td>
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<tr>
<td>No Strategy</td>
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<td>11.57</td>
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<td>1.92</td>
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</tr>
</tbody>
</table>

* Some subjects reported of using more than one cue