Chunking and compound cueing of movement sequences:

Learning, retention and transfer

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Key words: Part-whole practice; Sequence learning; Chaining; Imitation; Motor learning
Abstract

When teaching a complex sequence a teacher often ‘chunks’ the sequence into components. However, this strategy may not always benefit learning, and sometimes may be detrimental. We hypothesized that this is because chunking deprives learners of compound cues that could otherwise aid recall. To test this, subjects learned nine-item movement sequences, either as three, three-item chunks or as one nine-item series. To undermine compound cueing, some sequences had several movements in common. Learning a sequence in chunks: (i) impaired motor skill acquisition only when subjects could have exploited compound cues, and (ii) caused subjects to adopt an alternative recall strategy, which transferred to novel sequences even though it was detrimental to recall.
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**Introduction**

Imitation is an essential vehicle for human motor skill learning. When this vehicle is used to teach a complex skill, the teacher often takes account of the learner’s short-term memory by breaking the behavior into chunks, each of which might be demonstrated and practiced in turn. For example, when teaching a child to tie his or her shoelaces, one might separately demonstrate and have the child practice one chunk of movements, and then do the same for the second chunk of movements. As Miller (1956) and others have noted, the concept of a “chunk” is important for understanding various cognitive functions, including learning and memory. However intuitive it might seem to teach a complex skill as chunks there is disagreement as to whether this strategy is beneficial or harmful for learning (for review, see Cunningham, 1971). The question then is why might this widespread pedagogical technique sometimes impede skill learning? One attractive hypothesis emerges from experiments on the serial recall of word lists. In particular, it has been shown that in recall subjects rely on “compound cues” (Chance & Kahana, 1997; Kahana & Caplan, 2002): where multiple items in a series are combined and used to aid recall of subsequent items in the series. For example, Chance and Kahana (1997) asked subjects to learn two different lists of words that had items in common. During recall of a list, subjects were slow in recalling those items that immediately followed multiple, but not single shared components. Kahana and colleagues suggested that when two lists of items share multiple components, associative interference undercuts the compound cue’s ability to aid recall, as the common items are ambiguous with respect to which sequence’s items they should cue.

Mindful of these results with word lists, we asked whether compound cueing plays a
comparable, important role, in the learning of complex movement sequences. In particular, we asked whether teaching a sequence in chunks might impair learning by undermining subjects’ ability to form compound cues to recall. It is important to note that although both “compounding” and “chunking” refer to the combination of items in memory, when we refer to “compound cues” and “chunks” the terms have different referents. Compound cueing refers to the combination of multiple prior items in memory to aid recall of subsequent items (Chance & Kahana, 1997). For example, recall of items A.B.C would assist recall of item D. In contrast, chunking refers to the representation of multiple items as a single memory unit, to make the processing of a sequence more efficient (Sakai, Kitaguchi, & Okihide, 2003). Thus, items A.B.C might comprise one chunk, and items D.E.F might represent another, with no enforced associative link between the two chunks.

Here we sought to reconcile some of the controversy in the literature regarding the merits of teaching a sequence in chunks. We used a paradigm that Agam, Bullock, and Sekuler (2005) introduced for the study of human imitation. This task was attractive because imitation is frequently used to teach complex skills to a would-be-learner. In the task, subjects viewed a disc moving in two dimensions through a series of quasi-random directions. After the disc stopped moving and had disappeared, subjects attempted to reproduce the movement that they had seen, by moving a hand-held stylus across a graphics tablet. We examined how teaching a sequence in a Chunked versus a Complete practice schedule affects subjects’ ability to learn, retain and transfer a new skill (i) when compound cues can be effectively used to aid recall, and (ii) when compound cues cannot be used for recall. To manipulate the availability of compound cues we adapted the paradigm introduced by Kahana and colleagues (Chance & Kahana, 1997; Kahana & Caplan, 2002) whereby some sequences had multiple movements in common (Repetition trials), and others did not (No Repetition trials).

We hypothesized that chunking would impair learning by disrupting subjects’ ability
to form compound cues for recall. As such we predicted that chunking would be
detrimental to learning when compound cues could otherwise have been used effectively
for recall (i.e. the No Repetition sequences), however would have no effect on performance
when compound cues could not have been used for recall (i.e. the Repetition sequences).
Such a finding would not only extend the findings of Chance and Kahana, regarding the
use of compound cues in recall, from the verbal learning domain to the motor learning
domain, but it would provide important insights into how motor sequences should be
presented during learning.

Methods

Subjects

24 subjects participated (19 females), between 18 to 34 years old (mean = 22.75,
standard deviation = 4.86). All subjects had normal or corrected to normal vision and
were strongly right-handed as determined by the Edinburgh Handedness Inventory
(Oldfield, 1971). Subjects provided written informed consent and the experimental
protocol had been approved by Brandeis University’s Committee for the Protection of
Human Subjects.

Stimuli

Stimuli were generated and presented in a fashion similar to that reported elsewhere
(Agam et al., 2005; Agam, Galperin, Gold, & Sekuler, 2007), and illustrated in Figure 1.
Stimuli were presented on a 51 cm computer monitor, viewed from a distance of 57 cm.
Each stimulus comprised the movements of a yellow disc on a black background. The 1°
diameter disc appeared first at the center of the computer display, and then 500 msec later
began moving along a series of connected, randomly-oriented linear segments. Each
segment was 1.5° of visual angle long and took 500 msec to complete. In order to prevent
illusory distortions of the linear paths (Sekuler, Siddiqui, Goyal, & Rajan, 2003), successive segments were separated by a 500 msec pause in the disc’s movement. Before the experiment began, eight different movement sequences were generated offline and stored for later presentation. For each subject four of these sequences were assigned to-be-learned, and the other four were reserved to be used as novel sequences presented at the end of testing; this assignment was counterbalanced across subjects and conditions. The movements in all eight sequences obeyed the following constraints: the angular change in direction between any two successive segments was a random sample from a uniform distribution spanning 30° to 150°; no two segments were allowed to intersect one another; any direction of movement could occur only once in all the sequences, except when the experimental design explicitly called for repetition of a direction, as in Repetition sequences. For both the to-be-learned and novel sequences, within one of the sequences the middle chunk was replaced with the middle chunk of another sequence in the set of four. As the top panel of Figure 2 suggests, there were two trial types within each set of four sequences: two No Repetition sequences (which were different from one another) and two Repetition sequences (in which segments 4-6 were identical).

For trials in the Complete conditions, shown in Figure 1A, the yellow disc appeared on the screen and traced out a path of nine segments, the total time to finish each sequence was 9 seconds. When the stimulus completed the entire sequence the yellow disc disappeared from the screen. Five hundred msec later a blue disc appeared in the center of the screen, which cued the subject to initiate a response by moving the handheld stylus over the graphics tablet, reproducing from memory the path that the yellow disc had taken. For Chunked trials, shown in Figure 1B, instead of viewing and then reproducing all nine segments at once, subjects viewed and reproduced segments in groups of three. First, they saw and reproduced segments 1-3; this was followed by the same for segments 4-6; finally segments 7-9 were viewed and reproduced. The stimulus starting position of
segments 4 and 7 began at the stimulus ending position of segments 3 and 6, respectively. For each chunk, the blue response disc appeared at the initial starting position of each chunk (i.e. the starting position of segments 1, 4 and 7). As the presentation time for each chunk was three seconds, the total stimulus viewing time was nine seconds, the same as in the Complete mode. In both Chunked and Complete modes subjects received no visual feedback regarding accuracy of performance. One second after a movement sequence finished, signaled by lifting the pen from the tablet, subjects saw an instruction that a new sequence would be presented. Note that the disc’s movements define a path without leaving a trace on the display; as a result, the entire path was never visible all at once.

Procedure

Instructions and practice. To initiate a trial, subjects touched a stylus to 30×24 cm graphics tablet. Displayed text informed subjects that they would see a yellow disc, which would move along a path comprising nine segments. When the yellow disc had finished tracing the nine segments, it would disappear and be replaced by a blue disc. Subjects were instructed that when the blue disc appeared they were to use the stylus and graphics tablet to reproduce the path of the yellow disc as accurately as possible with their right hand. They were told that each sequence contained nine segments, and they should include nine segments in any reproduction. Subjects were instructed to lift the stylus from the tablet when they were finished responding. All subjects were given four practice trials to familiarize themselves with the stimuli and task. Stimuli from these practice trials were not used in any of the experimental conditions.

Experimental design. Figure 2 summarizes the experimental design. The experiment proper began with a series of baseline measurements where the stimuli were the four sequences that he/she would later be trained on. The four stimuli were presented twice each in block-randomized order, with the constraint that the same sequence could not
appear twice in succession. Two of the sequences were Repetition trials and two were No Repetition trials. Next, subjects entered into the Training phase of the experiment where they saw ten repetitions of each of the sequences according to a Complete or Chunked practice schedule. All subjects were told that they were going to learn four different nine-segment sequences. Subjects assigned to the Complete practice schedule were told that they would see each sequence ten times, in a randomly interleaved fashion, and that after each stimulus presentation they should use the stylus and graphics tablet to reproduce the nine-segment sequence that they had seen. Subjects assigned to the Chunked practice schedule were told that they were going to learn each of the ten nine-segment sequence as three chunks of three segments. They were told they would see segments 1-3, after which the blue disc would appear and they should reproduce segments 1-3. When they completed reproducing the first chunk they would then be shown segments 4-6, after which time the blue disc would appear, signaling that they should reproduce segments 4-6. Finally, segments 7-9 were shown, and these, too, had to be reproduced from memory. This was the only phase of the experiment where the two groups of subjects were treated differently. Next, the experiment’s Test phase assessed any carryover of the learning acquired during the preceding Training phase. For all subjects, sequences were presented and reproduced as complete nine-segment models. For each subject, the four sequences on which he/she had been trained were presented two times, in exactly the same manner as that of the Baseline phase.

On day two of testing, twenty-four hours after the first day’s testing, each subject returned for follow-up. This second day’s testing began with the experiment’s Retest phase, which measured subjects’ retention of the four sequences on which they had been trained the previous day. The presentation was in the same manner as the Baseline and Test phases. Subjects were next tested on their ability to reproduce their previously-learned sequences, but now with the sequences’ constituent components
reordered. For this Reorder phase of the experiment, the nine-movements in each sequence
groups, such as \((A_1.A_2.A_3.)\), \((B_1.B_2.B_3.)\) and \((C_1.C_2.C_3)\). The three movement groups
were re-ordered in one of three possible ways: (1) \(B_1.B_2.B_3.C_1.C_2.C_3.A_1.A_2.A_3\); (2)
selected which best preserved the angular constraints placed on the original stimulus
construct. In the reordered condition the minimum angular distance between two
successive segments was \(30^\circ\) and the maximum was \(153^\circ\). Each of the four reordered
sequences was presented and reproduced twice as one unbroken, nine-movement sequence
in a in block-randomized order. In the final, Novel phase of the experiment, subjects
viewed and tried to reproduce four novel, nine-movement sequences. For half the subjects
in each group, *Complete* and *Chunked*, these novel sequences were ones with which the
other subjects in the group had been trained on the first day of testing. Each of the four
novel sequences was presented twice, in block randomized order. For each block of trials
seen on day two subjects got no information as to whether they had seen the stimuli
before.

*Analysis*

We were interested in the effect that each training schedule had on subsequent
performance, rather than on performance during training. Therefore, analysis included
trials from the Baseline, Test, Retest, Reorder and Novel phases. Within each of these
blocks of trials subjects in both groups (i.e. *Complete* and *Chunked*) were tested in
identical ways, which allowed direct comparison of the two groups’ performance. Data
from the Training phase were not included in the analysis as the two groups of subjects
were tested in different ways as these data were not comparable between the two groups.

To score the accuracy of performance, reproductions were segmented and analyzed
for fidelity to the corresponding stimulus, using a method described in detail elsewhere (Agam et al., 2005, 2007). Briefly, a computer algorithm searched for places in a reproduction where the stylus stopped moving for more that 40 msec or changed direction by more than 5°. Pairs of successive critical points, which were assumed to represent breaks between segments, were then connected with a straight line. These lines were taken as the reproduction’s movement segments. Only reproductions in which the segmentation algorithm yielded nine segments were included in the analysis. For every subject, at least five out of eight trials (within every block) contained nine segments, and were thus included in the analysis. A total of 88.75% and 85% of trials were included in the analysis for the Complete and Chunked groups, respectively.

We analyzed two dependent variables: First, average error, defined as the mean absolute difference in orientation between each segment in the reproduction and the corresponding segment in the stimulus. Average error is expressed in units of degrees of rotation. This dependent measure represents an aggregate of three sources of error: imprecision during the visual encoding of the stimulus sequence, noise introduced during the time the stimulus was held in memory, and any effect of imprecision on motor control. Second, reaction time, defined as the time in seconds between the appearance of the blue disc on the screen and the initiation of the subject’s response. This dependent variable represents an index of the time taken to pre-plan the sequence of movements to be produced during the reproduction.

Reproductions from each block of trials (Baseline, Test, Retest, Reorder and Novel) were submitted to a repeated measures analysis of variance (ANOVA) with a within-subjects factor of trial type (Repetition versus No Repetition), and the between subjects factor of training schedule (Complete or Chunked). For conciseness only statistically significant findings are discussed. However, for completeness all data are summarized in Table 1.
Results

Skill learning

As expected, during the Baseline phase, the groups did not differ, either on accuracy ($p > 0.237$) or on reaction time ($p > 0.486$). Note that at baseline testing both groups of subjects were tested the same way and had no information as to which group they would be assigned during Training.

As the two groups did not differ at Baseline testing, the test phase of the experiment represents a measure of skill learning. For the Test phase, the accuracy measure showed a significant interaction between group and trial type ($F_{(1,22)} = 5.130, p = 0.034$). This reflects the fact that, as can be seen in Figure 3a, the Complete group outperforms the Chunked group on No Repetition trials ($t = -2.113, df = 22, p = 0.046$) but not on Repetition trials ($t = -1.32, df = 22, p = 0.896$). There was no significant main effect of group ($p > 0.217$) or condition ($p > 0.637$) on accuracy, and no significant main effect or interactions for the reaction time measure ($p > 0.238$).

If the interaction described above arose from the fact, as hypothesized, that subjects in Chunked group were unable to use compound cues to recall the sequence on No Repetition trials, the Complete group’s performance advantage on the No Repetition trials would be most evident for segments occupying serial positions 4 and 7. After all, these are the positions in the sequences at which the Chunked group could not use prior items to aid recall, as segments 4 and 7 represented the first item in the chunks. To test this we compared each group’s accuracy of reproduction at segment positions 4 and 7 during No Repetition trials in the experiment’s Test phase. Figure 3b shows the serial position curves for the Complete and the Chunked groups on the No repetition trials. Note that Complete group shows a clear advantage over the Chunked group at segment position four ($t = -2.814, df = 22, p = 0.01$) but not seven ($t = -0.212, df = 22, p = 0.834$).
Skill retention and transfer

Performance during the Retest phase of the experiment is a measure of skill retention, and performance on Reorder and Novel phases serve as a measure of skill transfer. We observed no significant effects or interactions on skill retention for either accuracy ($p > 0.127$) or reaction time ($p > 0.142$). Effects do emerge, however, on measures of transfer, in the Reorder and Novel phases, for reaction time but not accuracy ($p > 0.071$). For reaction time we see a significant main effect of group in both the Reorder ($F_{(1,22)} = 5.499, p = 0.028$) and Novel phases ($F_{(1,22)} = 6.644, p = 0.017$).

Specifically, subjects in the Chunked group took longer to prepare their responses than did their counterparts in the Complete group (Figure 4a). We also found a significant main effect of trial type in the Reorder phase ($F_{(1,22)} = 12.595, p = 0.002$) with subjects taking longer to prepare their responses on Repetition trials compared to No Repetition trials (Figure 4b).

Discussion

Our results suggest that learning a movement sequence according to a chunked practice schedule impairs skill performance following training only when subjects could otherwise have made use of compound cues for recall. This effect was shown by the Chunked group’s reduced accuracy in reproduction immediately following training, but only for the No Repetition trials. For these trials the Chunked group were unable to use segments 1-3 as a compound cue for recall segment 4, whereas the Complete group were able to exploit compound cues. For the Repetition trials, as predicted by Chance and Kahana (1997), associative interference seemed to prevent both groups from using compound cues to recall. These findings extend the results of Chance and Kahana (1997) from the verbal domain to the motor domain. It is important to note that our results cannot be accounted for by the fact that the Chunked group were trained on sequences in
a different fashion than how they were tested. If such an explanation could account for the
performance of the *Chunked* group then we would have expected a performance detriment
for these subjects across all trial types. Such a finding was not observed, we specifically
saw a benefit for *Complete* group subjects *only* on trials where compound cues could
otherwise have been exploited for recall.

Our results also show that training schedule influences the way in which subjects
encode a sequence and that this transfers to novel sequences. In particular, results from
the Reorder and the Novel phases showed that the *Chunked* group subjects took longer to
prepare their responses. Such a finding has important implications for motor learning, as
it suggests that the way in which information is initially coded for recall persists and
continues to influence performance even when that coding is detrimental to recall.

An analysis of the serial position curves during the experiment’s Test phase revealed
that the *Chunked* and *Complete* groups differed significantly in reproduction accuracy for
segments in the fourth serial position but not the seventh serial position. The difference at
the fourth serial position is consistent with the idea that the *Complete* group exploits
compound cues derived from segments 1-3 as an aid to recall the next segment. The
*Chunked* group training schedule inhibited the development of such cues, which causes
subjects in that group to be disadvantaged at segment position four. At segment position
seven we believe that the *Complete* group is unable to use compound cues for recall as
their performance on the segments immediately preceding seven is so poor, making these
segments ineffective cues for recall. This explanation might account for the fact that
subjects seemed not to use compound cues to recall sequences during the *Baseline* phase,
where there was no observed benefit on *No Repetition* trials. The fact that we observed no
benefit of *No Repetition* trials during the Baseline phase suggests that before a sequence is
learned subjects may be encoding sequences in a different manner.

So how do subjects encode a novel sequence? It has been suggested that recall of
novel sequences makes use of positional information. However the role of positional information decreases as a sequence is learned (Hitch, Fastame, & Flude, 2005).

“Positional cues” refer to encoding each item in terms of its position within the sequence (Lee & Estes, 1977). Our results provide some support for this hypothesis. For the trials in the Reorder phase, subjects took longer to prepare their responses for Repetition trials compared to No Repetition trials. In other words, for Repetition trials there is a heavy burden on response preparation when required to reproduce sequences that have been presented in a different order, suggesting that, for these trials types, items are represented in terms of position within the sequence. Our results therefore are consistent with the idea that novel sequences are represented in terms of positional information, and as a sequence is learned such information is replaced, or supplemented, by compound cues. Under conditions where compound cues are unavailable, as is the case for our Repetition trials, subjects will continue to rely on positional information to cue recall.

Our results show that the benefits of a Complete practice schedule disappeared on retest 24 hours later, where no significant difference between the two groups was observed. This suggests that the structure of memory (Complete versus Chunked) can differentially affect skill acquisition and retention. This finding is consistent with studies of contextual interference, which compares performance of subjects who learn skills under: (i) a random schedule, with the skills being randomly intermixed during acquisition, or (ii) a block schedule, with the skills being segregated from one another during acquisition. Compared to subjects who learned under a random schedule, subjects who learned under blocked conditions show better initial skill acquisition but poorer retention of the skill. This effect has been demonstrated across a wide range of motor skills (Bortoli, Robazza, Durigon, & Carra, 1992; Brady, 1997; Goodwin & Meeuwsen, 1996; Hall, Domingues, & Cavazos, 1994; P. J. K. Smith, 2002; P. J. Smith & Davies, 1995; P. J. K. Smith, Gregory, & Davies, 2003). Wright, Black, Immink, Brueckner, and Magnuson (2004) have
demonstrated that subjects assigned to blocked training show spontaneous sequence chunking that is transient, however this spontaneous chunking persists longer for random participants. Our results extend such findings, suggesting that experimenter-imposed chunking may also differentially influence skill learning and retention.

It is important to note that our results do not support a claim that chunking is never beneficial for learning. After all, our results reflect a particular form of chunking, one that is imposed upon the learner. There is a great deal of evidence that when learning motor sequences subjects spontaneously develop motor chunks (W. Verwey, 1996; W. B. Verwey & Eikelboom, 2003). When chunking is not imposed, but is generated by the learner, there is strong evidence that it promotes efficient processing of the to-be-learned sequence, and aids learning. This point has been demonstrated with a task like the one used in the present study (Agam et al., 2007) and in an experiment using trial-and-error acquisition with a sequence-learning task (Sakai et al., 2003). If there were a difference between experimenter-imposed and spontaneous chunking, one might wonder about the sources of that difference. Some evidence from our laboratory suggests that during learning signs of spontaneous chunking of movement sequences are transient, being evident early in learning, but then disappearing as practice proceeds (Agam et al., 2007).

With this result in mind, we speculate that early in learning, subjects represent a sequence in chunks, but as mastery is approached the chunks act as compound cues to recall, allowing associative links to form between chunks. Studies are underway in our laboratory to investigate the nature and impact of differences between spontaneous, learner-generated chunking and chunking that is imposed upon the learner.

In conclusion, our results suggest that learning a movement sequence in chunks will be detrimental for motor skill learning if the chunking deprives subjects of compound cues that might otherwise aid recall. Our results also suggest that chunking is detrimental to motor skill transfer as this method of training encourages subjects to rely on an encoding
strategy that does not make use of compound cues to recall. Moreover, this influence seems to carry over to new sequences, even when such a strategy is suboptimal. These findings have important implications for education, suggesting that forcing a would-be-learner to learn individual components of a motor sequence in isolation will impair learning and transfer of a motor skill if the skill might otherwise have benefited from compound cues to recall.
References


Author Note

The authors thank Daniel Bullock for thoughtful comments on an earlier version of this manuscript, and Yigal Agam, Jessica Maryott and Brian J. Gold for assistance. Supported by NSF grant SBE-0354378 (Center for Excellence in Learning, Science, Education and Technology).
Table 1

*Table illustrates mean (and standard deviation) of error and reaction time, for each block, group and trial type.*

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<th>TEST</th>
<th>RETEST</th>
<th>REORDER</th>
<th>NOVEL</th>
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Figure Captions

Figure 1. Figure illustrates the series of events for the: a) Complete and b) Chunked trials. The yellow disc represents the movement of the stimulus. Note that the disc’s movement did not leave a trace on the display. The appearance of the blue disc represents the cue for subjects to initiate their response. Once again the blue disc moves simultaneous with the subject’s movement and does not leave a trace on the display.

Figure 2. Schematic of sequence presentation for both the Complete and Chunked groups on days one (top) and two (bottom). Segments highlighted in red represent the section in the sequence that is either a Repetition or a No Repetition. The top two sequences in each block (shown in bold and italicized) illustrate an example of Repetition sequences and the bottom two sequences illustrate an example of No Repetition sequences. During the training phase the chunked group were shown each sequence as three 3-item chunks (indicated by enclosing parenthesis) and the complete group viewed and reproduced all nine segments at one. This is the only phase of the experiment where the two groups were treated differently.

Figure 3. a) Absolute error (in degrees) for Repetition and No Repetition trials in the test session (immediately following training). Error bars represent between-subject SEM. b) Mean absolute error (in degrees) for each segment position in the Test phase for No Repetition trials. Results are shown separately for Chunked and Complete groups. The grey vertical bars highlight segment positions four and seven, where we had an a priori hypothesis that the complete group would out-perform the chunked. Note that these positions represent the first item of the second and third chunk for the Chunked group, as such we predicted that these subjects would be unable to use compound cues to recall these items. Error bars represent between-subject SEM. * p < 0.05, ** p < 0.01

Figure 4. Mean Response time (in seconds) for: a) the Complete and Chunked group in the reorder and novel sessions and b) the Repetition and No Repetition trials in the reorder session. Error bars represent between-subject SEM. * p < 0.05, ** p < 0.01
Chunking, compound cueing and learning, Figure 2

### Day One

#### Baseline

**Complete Group**
- G: G, G, G: B, B: h, h
- D: D, D: E, E, E: F, F, F
- x2

**Chunked Group**
- G: G, G, G: B, B: h, h
- D: D, D: E, E, E: F, F, F
- x2

#### Train

**Complete Group**
- G: G, G, G: B, B: h, h
- D: D, D: E, E, E: F, F, F
- x10

**Chunked Group**
- D: D, D: E, E, E: F, F, F
- x10

#### Test

**Complete Group**
- G: G, G, G: B, B: h, h
- D: D, D: E, E, E: F, F, F
- x2

**Chunked Group**
- D: D, D: E, E, E: F, F, F
- x2

### Day Two

#### Retest

**Complete Group**
- G: G, G, G: B, B: h, h
- D: D, D: E, E, E: F, F, F
- x2

**Chunked Group**
- G: G, G, G: B, B: h, h
- D: D, D: E, E, E: F, F, F
- x2

#### Recorder

**Complete Group**
- C: C, C: A: A, A: B, B, B
- B: B: B: G: G: G, G: h, h
- F: F: F: D: D: D: E, E, E
- x2

**Chunked Group**
- C: C, C: A: A, A: B, B, B
- B: B: B: G: G: G, G: h, h
- F: F: F: D: D: D: E, E, E
- x2

#### Novel

**Complete Group**
- P: P, P: O: Q, Q, Q: R: R, R: R
- x2

**Chunked Group**
- P: P, P: O: Q, Q, Q: R: R, R: R
- x2

Chunking, compound cueing and learning, Figure 3

(a) 

(b)
Chunking, compound cueing and learning, Figure 4

(a) 

(b)