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Short-term memory coding in children with intellectual disabilities

Running Head: Short-term memory coding and ID

Key Words: Intellectual disabilities, children, short-term memory, memory coding

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Abstract

Children with intellectual disabilities (ID) and peers matched for mental (MA) and chronological age (CA) carried out picture memory span tasks with phonologically similar, visually similar, long, or non-similar named items, to examine visual and verbal coding strategies. The CA group showed effects consistent with advanced "verbal" memory coding (phonological similarity and word length effects). Neither the ID nor MA groups showed evidence for memory coding strategies. However, children in these groups with mental ages above 6 years showed significant visual similarity and word length effects, broadly consistent with an intermediate stage of "dual" visual and verbal coding. These results suggest developmental progressions in memory coding strategies are independent of ID status and in line with mental age.

The purpose of the current study was to examine memory coding on a pictorial memory span task in children with and without ID, within the framework of the working memory model devised by Baddeley and Hitch (1974; Baddeley, 1986; 2007). This influential model proposes a number of components with specialised and interacting roles. Overall attentional control is provided by the “central executive”. Two subsidiary “slave systems” provide active storage for speech-based information (the “phonological loop”) and visual/spatial information (the visuospatial sketchpad). The “episodic buffer” (Baddeley, 2000) acts as a “back-up store” and integrates information from different modalities and systems, including visual/verbal modalities and long-term knowledge. This paper concerns short-term memory coding and the strategic conversion of visual, but nameable, input into phonological codes.

According to the framework of the working memory model (Baddeley, 1986; 2007), items that are spoken have automatic access to the “phonological store”, one of the two components of the phonological loop. Phonological, or verbal, codes are created by the input itself. Visual items that can be named (e.g. pictures, written words, written letters) require an additional phase of phonological recoding to “convert” the visually presented material into a phonological code. Once this code has been created, the material can be stored in the phonological loop and verbally rehearsed to avoid decay in this time-limited store, just as automatically entered material can be. This latter, “indirect” route requires the individual to adopt a verbal recoding strategy by using the “articulatory control process”. Generally, unless blocked from using this strategy by articulatory supression, adults will use phonological coding to recall visually presented nameable stimuli. There are many demonstrations of phonological similarity effects for similar sounding written letters or words in adults, indicative of this verbal recoding (e.g.

Conrad & Hull, 1964, Baddeley, 1966). Note that although Baddeley (1986) argues for confusion in the phonological store, some authors point out that confusion at recall or reconstruction is also possible (e.g. Cowan, Saults, Winterowd & Sherk, 1991; Hasselhorn & Grube, 2003).

Recall of visually-presented phonologically encodable material provides a particularly interesting test of short-term memory coding and strategy use. Conceptualisations of how serial recall operates generally postulate that stored memory traces are used at the recall phase to “reconstruct” the items based on the information or features that remain (e.g. Frick, 1988a; 1988b). If the memory trace is stored in terms of phonological characteristics, the individual must consult what remains of the sound trace and attempt to reconstruct the items. For items stored in terms of their visual characteristics, reconstructing lists of items would proceed by reconstructing items based on the remaining visual features. Manipulating feature similarity is one way of disrupting the serial recall process. For example, for a child using a visual coding strategy, reconstructing items with common visual features (visually similar pictures) would be more difficult than reconstructing items that do not share visual features. Similarly, for a child using a verbal strategy, this reconstruction process would be more difficult for items sharing phonological characteristics (rhyming items).

The use of verbal recoding relies on translation of visual input into a phonological code via the articulatory rehearsal process (Baddeley, 1986; 2007). An additional role for the articulatory rehearsal process is that of verbal rehearsal, recitation of the contents of the phonological store to forestall decay. Verbal rehearsal is often inferred from the presence of word length effects; long-named items are more poorly recalled than shortnamed items as they take longer to rehearse sub-vocally (Baddeley, Thomson & Buchanan, 1975). There is much debate over whether word length effects always indicate verbal rehearsal (e.g. Cowan, Day, Saults, Keller, Johnson & Flores, 1992; Henry, 1991; Henry, Turner, Smith & Leather, 2000, Romani, McAlpine, Olson, Tsouknida & Martin, 2005; Yuzawa, 2001). Nevertheless, a conservative and relatively uncontroversial assumption would be that word length effects in the picture memory span task indicate verbal coding (or phonological recoding); slightly more controversially, word length effects reflect either a preparation and/or recitation of the verbal output sequence, a simple naming strategy or full cumulative verbal rehearsal. Simple naming or phonological recoding may be a precursor to the development of full verbal rehearsal (Gathercole & Hitch, 1993; Henry & Millar, 1993; Yuzawa, 2001). Importantly, these assumptions are much easier to defend if the potentially confounding effects of verbal output are controlled (e.g. Henry, 1991), therefore, all span tasks in the current study required non-verbal (picture pointing) recall.

Hence, the picture memory span task was used to examine verbal rehearsal, or at least verbal recitation strategies, via manipulating the articulatory length of picture names. Items with longer names are not more difficult to *reconstruct* (as occurs in visual and phonological similarity effects); in fact, they may be easier (Brown & Hulme, 1995; Romani et al., 2005). However, because longer names take longer to articulate and, hence, allow more time for decay of the memory trace, those children using verbal rehearsal or verbal recitation of the output sequence will recall fewer long items according to the working memory model (Baddeley, 1986). Note that the beneficial effects of item length on “redintegration” or reconstruction are more than outweighed by the detrimental effects of longer articulatory length during the verbal recitation or rehearsal of the output sequence (Cowan, Wood, Nugent & Treisman, 1997).

Experimental evidence is consistent with a gradual development in the strategic approach to memory coding in the picture memory span task. There is evidence for the emergence of phonological similarity effects from around 5 or 6 years, suggestive of "covert speech" coding (Conrad, 1971); and evidence of visual but not phonological coding in 4- and 5-year-olds (Brown, 1977; Hayes & Shulze, 1977). Word length effects seem to emerge around 7 years on picture memory span tasks where children are not allowed to "name" or label items during input (Halliday, Hitch, Lennon & Pettipher, 1990; Henry, 1991; Henry et al., 2000; Hitch, Halliday, Schaafstal & Heffernan, 1991).

More recent work has tried to document the development of visual similarity, phonological similarity and word length effects in more detail. Although few studies have compared all three effects together, the evidence, again, indicates a stage-like development. First, at the preschool level, children appear to use no particular coding strategy (Palmer, 2000); next they move to using visual strategies at around 5 years (Hitch, Halliday, Schaafstal & Schraagen, 1988; Hitch, Woodin & Baker, 1989; Hitch et al., 1991; Longoni & Scalisi, 1994; Palmer, 2000); followed by a period of "dual" visual and verbal coding between 6 and 8 years (Palmer, 2000); and finally the most mature stage of predominantly verbal strategy use emerges at around 10 years (Hitch et al., 1988; 1989; 1991). There are at least two key phases in the progression towards verbal/phonological encoding: (1) the child learns to verbally recode pictorial material; and (2) the child repeats these names singly or in groups during the input and/or preparation for recall period. This second "verbal rehearsal" stage may be a two-phase process developing from simple naming to cumulative rehearsal. Both stages require the use of a *voluntary strategy*. The process of "naming" pictures may need to become relatively habitual and rapid (possibly linked to the process of learning to decode text) before it is used for verbal recoding, naming and rehearsal (Henry & Millar, 1993).

In the interim phases, children may also be relying on concurrent visual codes (Palmer, 2000), and this may continue into adulthood in circumstances when verbal coding is made difficult (Logie, Della Sala, Wynn & Baddeley, 2000; Walker, Hitch & Duroe, 1993). Hitch et al. (1989) and Palmer (2000) both noted, regarding the developmental "shift" from phonological codes to visual codes, that the more developmentally advanced verbal coding strategy is simply added to the child's repertoire, rather than replacing the earlier visual strategy.

The characteristics of short-term memory development in children with intellectual disabilities (ID) are less clearly specified. Burack and Zigler (1990) found poorer performance on a picture memory matching span task by children with ID, in comparison to mental age matched controls, but did not test any of the described effects. Rosenquist, Connors and Roskos-Ewoldsen (2003) found visual similarity effects in adolescents with mild ID (mean mental age 8 years) on a picture matching span task, which is consistent with their participants being at the visual encoding or dual visual and verbal coding phase (Palmer, 2000).

Other available evidence derives from auditory verbal word span tasks and is consistent with the view that children with ID encode auditory information phonologically (the "automatic route"), but do not use verbal rehearsal strategies. Phonological similarity effects have been found using auditory presentation of rhyming words; although they may be attenuated due to the absence of *additional* confusion caused by verbal rehearsal (Hulme & Mackenzie, 1992; Jarrold, Baddeley & Hewes 2000; Rosenquist et al., 2003; Varnhagen, Das & Varnhagen, 1987). Some studies have found no evidence for word length effects in children with ID (Hulme & Mackenzie, 1992; Rosenquist et al., 2003), or for speech rate differences between those with ID and controls that might imply rehearsal differences (Kanno & Ikeda, 2002). Other studies *have* found word length effects (Jarrold et al., 2000; Kanno & Ikeda, 2000; Kittler, Krinskey-McHale & Devenny, 2004; Russell, Jarrold & Henry, 1996), but an argument has been put forward that these reduce or disappear when the potentially confounding effects of verbal output are controlled (Jarrold et al., 2000). Overall, it can be suggested that children with ID are unlikely to use verbal rehearsal on auditory verbal word span tasks, although they do use verbal coding when the input is verbal, i.e. the "automatic route".

Henry and MacLean (2002) also proposed that working memory in children with ID was characterised by an absence of voluntary verbal strategies. They found, for children with ID, that auditory verbal word span was poorer than mental age level, whereas, spatial and visual short-term memory span exceeded mental age levels (although still remaining poorer than chronological age level). They suggested that on memory span tasks where verbal strategies could be used to enhance performance, children with ID were disadvantaged because they were less likely to use such strategies (e.g. Belmont, 1978; Brown, 1974; Ellis, 1970; Jarrold et al., 2000). By contrast, spatial span and visual span, by virtue of their emphasis on non-verbalisable memory materials, are not tasks in which verbal strategies can easily be used; hence performance deficits are absent or reversed. Corroborating evidence was provided by Rosenquist et al.

(2003) who found that children with ID performed *better* on a non-verbal visual complexity task than mental age matched peers.

However, to date, previous work has not addressed potential differences in rehearsal or verbal coding strategies for visually presented material that can be named (i.e. familiar pictures). Nor has the relationship between the use of verbal coding been examined amongst individuals with ID, relative to their current level of intellectual development. Here, additional analyses of children with ID who have higher (over 6 years) and lower (under 6 years) mental ages are included in order to begin to map out the developmental trajectory of strategic memory coding in those with ID on the picture memory span task.

Therefore, children studied sets of pictures that varied in terms of visual similarity, phonological similarity of object names, and length of object names in comparison to a set of control pictures. The predictions were as follows. Typically-developing children of 10 years (CA group) should show evidence of phonological similarity and word length effects, consistent with the most mature verbal recoding strategy and the additional use of verbal rehearsal (although note reservations around the straightforward assumption that word length effects always reflect verbal rehearsal even when verbal output is controlled). Typically-developing children of 5 years (MA group) should show evidence of visual similarity effects, consistent with the less mature phase of visual coding. Predictions for children of 10 years with ID were speculative: if they performed at a level commensurate with their mental age level, they should show recall levels and memory coding in line with the MA group (hence, visual similarity effects). Importantly, however, memory coding may be related to mental age level rather than intellectual disability per se, so a further prediction was that those with ID who had more advanced mental ages may also show more advanced memory coding strategies.

Method

Design

A two-factor mixed design included one between participants factor, group (3 levels), and one repeated measures factor, picture type (4 levels). Three groups of children were: 10-year-old children with ID; 10-year-old typically-developing children (CA comparison group); and 5-year-old typically-developing children (MA comparison group). Four measures of picture span included: pictures with one-syllable names that were neither visually nor phonologically similar ("control"), pictures with phonologically similar names ("phonologically similar"), pictures which looked visually similar ("visually similar"), and pictures with longer names (three-syllables, "long").

Participants

There were 36 8- to 13-year-old children with ID (mean chronological age 10 years 6 months), all attending special schools or special educational units within mainstream schools in England. Children with nonverbal IQs in the ID range below 79 were included in this study; this represents a delay of at least three years compared to mainstream peers. Information on diagnosis was not specifically sought, therefore, the sample of children with ID is likely to be heterogeneous with respect to the aetiology of the ID. There were no participants with Down syndrome, however.

There were 62 typically-developing children, 30 4- to 5-year-old children in the mental age comparison group (mean chronological age 5 years 1 month), and 32 8- to 12-year-old children in the chronological age comparison group (mean chronological age 10 years), all drawn from mainstream schools in England. Only children with nonverbal IQs of 80 and above were included in these groups. Full details of the sample groups, including adjusted raw scores on the IQ measure are given in Table 1. There were no significant differences between the MA and ID groups in terms of mental age or raw ability scores on the Pattern Construction test from the BAS II (Scheffe tests: the CA group were higher on both as expected, $p < .05$). Similarly, there were no differences between the ID and CA groups in terms of chronological age (Scheffe tests: the MA group were younger as expected, $p < .05$).

Nonverbal IQ was estimated using the Pattern Construction subtest from the British Ability Scales II (BAS II, Elliott, 1996). Pattern construction is suitable for children with mental and chronological ages down to below three years and has UK norms, enabling all children in the current study to be assessed using the same measure. The test was selected based on previous research indicating that it was an appropriate measure across the age and ability range used here, distinguishing children in special and mainstream schools better than a verbal test covering the same age range (BPVS II: Henry & Gudjonsson, 2007). There is, in fact, no single UK-normed ability test of *both* verbal and nonverbal abilities that covers the mental age range from 3 to 18 years required here. Scores were pro-rated (there is one other nonverbal reasoning test in the BAS II battery, but it only covered the age range 5 to 18 years) and used to estimate an overall nonverbal reasoning index.

Note that estimating IQ can become difficult at lower ability levels; the BAS II provides non-verbal reasoning standardised scores down to IQ 47. Several children at lower ability levels in the ID group were assigned scores of 47 (n=12), but at least some of these scores will be too high because of the restricted low ability range, so caution must be used in interpreting the IQ scores. On the other hand, the range of estimates for mental age (test age equivalent) provided by the BAS II manual comfortably included *every* participant in this study, so every child could be assigned a mental age equivalent level based on raw scores. Hence, the mental age estimates are a more accurate reflection of the ability levels of our ID group than the IQ estimates. IQ estimates are, however, included in Table 1. Also included in Table 1 are the raw ability scores on the BAS II Pattern Construction test (the numerical difference in scores between the MA and ID groups was non-significant).

In accordance with ethical approval guidelines at the institution at which this research was carried out, informed written consent was obtained from parents prior to participation. Before sessions, the investigator also asked whether the child would like to participate. The task was popular and no child refused to take part.

Table 1 about here

Procedure and Materials

All children were tested at their schools in two sessions, presented to the children as an opportunity to do some "special work" with the Experimenter. The first session included Pattern Construction and two of the picture memory span tasks. The second session included the remaining two picture memory span tasks. The first session lasted approximately 25 minutes and the second session approximately 10 minutes.

The Picture Memory Task. There were four sets of nine items for this task, each set being used for one memory span measure. Each of the 36 items was a familiar, highly imageable object name, illustrated on a 14cm x 9cm white card as a black and white line drawing. The control object names were: kite, bus, frog, clown, cake, sheep, ring, owl, drum (mean Age of Acquisition (AoA) on a scale of 1-7 = 2.02, range 1.7-2.65; mean imageability on a scale of 1-7 = 6.39, range 5.95-6.7). The phonologically similar object names were: cat, hat, bat, pan, van, fan, hand, lamp, ant (mean AoA = 2.11, range 1.15-2.9, mean imageability = 6.24, range 5.9-6.7). The visually similar object names were: knife, torch, pen, nail, sock, spoon, tie, brush, key (mean AoA = 2.17, range 1.45-2.9, mean imageability = 6.17, range 5.8-6.45). Finally, the long object names were: banana, elephant, strawberry, butterfly, telephone, umbrella, ladybird, television, caterpillar (mean AoA = 2.2, range 1.7-2.55, mean imageability = 6.48, range 6.25-6.7). There were no differences between the item sets in terms of mean AoA or imageability. Ratings were from Morrison, Chappell & Ellis (1997).

The phonologically similar items were not all direct rhymes, because of the difficulty of obtaining enough highly familiar object names in such a set; but all items shared the same vowel sound which is regarded as the most important factor affecting phonological similarity for one-syllable items (e.g. Nimmo & Roodenrys, 2004). For one item in this set (fan), ratings of AoA and imageability were unavailable from Morrison et al. (1997), but the word was included given constraints on obtaining suitable words in this set and the fact that this item was familiar and could be unambiguously depicted as a line drawing. Visually similar items were illustrated as long thin objects, all at the same 45° angle. Short- and long-named objects were of one-syllable or three-syllables respectively and care was taken that illustrations were not visually similar. Examples of the pictures are given in Figure 1.

Figure 1 about here

Response boards were 42cm x 30cm in size and contained all nine object pictures from each stimulus set in a 3 by 3 array. Five response boards for each stimulus set were prepared and the nine object pictures in appeared a different random order on each one. This was to prevent participants learning the spatial locations of the items on the response boards during memory span tasks; response boards were changed with every memory trial (although note that this may have increased demands on selective attention for participants).

The memory task was presented as follows. Children were first shown the stimulus cards and they were named by the experimenter. Naming by the experimenter was necessary in order to ensure that children were given the correct labels for items, although the Experimenter did not encourage children to name pictures alongside her, to reduce the scope for priming verbal strategies. Children were then shown a response board and it was explained that all of the pictures in the card set were also shown on this board. Children were asked to look at a series of presented cards, beginning with lists of just one item, but progressing on to longer lists, and then to point to the cards they had seen in serial order on the response board. Each picture card was presented for approximately 1 second in the same spatial location and then removed from view. Previous work in this area has generally presented pictures in a fixed horizontal row, turning each card face down in turn (Hitch et al., 1988; 1989; Longoni & Scalisi, 1994).

This has the effect of introducing an additional element to the task, that of spatial location. To keep the task as similar as possible to verbal serial recall, the current study employed a sequential visual presentation whereby all items were presented in the same spatial location and cards were not placed face down in a left to right spatial array.

Children were instructed not to name the cards out loud to avoid adding overt verbal input (e.g. Hitch et al., 1991). If they were observed to do so, the Experimenter reminded them again. These instructions were largely successful, with the exception of 8 children with ID who persisted in naming pictures. For each analysis reported, an identical analysis excluding these 8 “namers” was carried out. In no case were the results different, therefore, analyses for the full sample only are reported.

Following presentation of the list of picture cards, one of the 5 response boards was revealed and the child attempted to point to the list items in serial order. The response choices included all 9 items in the pool such that item *and* order information was required, given the documented importance of the requirement for serial order report (Avons, 1998; Avons & Mason, 1999; Avons, Ward & Melling, 2004).

All of these methodological points (avoiding spatial cues, non-verbal recall method, serial order report) make the serial picture recall task as similar as possible to the analogous serial verbal recall task. They also ensure that if the child is using verbal coding, this has been the result of a deliberately employed strategy, not one encouraged by verbal labelling at input or verbal recall methods.

Four practice items and a smaller 30cm x 20cm response board showing the practice items (egg, fork, bike, shoe) in a 2 x 2 array were used to explain the task. Two trials using lists of one item and two trials using lists of two items were presented to each child. When introducing the lists of two items, the Experimenter specifically asked children to “point to the first picture first and the second picture second” to emphasise the order requirement. On rare occasions, extra practice trials were administered if the child understood that they were to recall the pictures, but failed to grasp the order requirement (i.e. recalled the correct pictures in the wrong order). During the span tasks, the Experimenter ensured that the order requirement was repeated if necessary.

The four memory span tasks were presented in counterbalanced order, two in session 1 and two in session 2. Tests began with lists of one item for the younger children and those with intellectual disabilities; tests began with two items for the older children and credit was given for passing list lengths of one. Three trials were presented at each list length and testing proceeded up to the next level provided at least two of the three trials were entirely correct (in serial order). Span score was the longest list correctly recalled on at least two out of three trials, with a bonus of 0.5 if one list at the next (failed) level had been correct (as two correct trials represented a “pass” at a particular span level, one correct trial represented a “half” pass).

Note that scores on visual memory span tasks can often be in the range of “one”, i.e. lower than auditory verbal span scores, particularly if a participant is using less mature visual coding strategies to recall the items (visual memory is hypothesised to hold much less material than verbal memory) or no coding strategies at all. Remembering one picture and locating it on a response board with 9 alternative choices is a non-trivial task for very low ability children, with a chance performance of 1 in 9. Very few children obtained scores of less than 1 that might be indicative of floor effects. There were two children with ID who obtained scores of 0.5 on visually similar pictures (i.e. one trial out of three correct), but their other scores were 1 or higher. One child with ID obtained scores of 0.5 on all picture types.

Reliability of the picture memory span task:

As the span tasks consisted of three trials at each list length, it was possible to calculate memory span scores from all trial 1 scores, all trial 2 scores and all trial 3 scores. Together with the overall span score, there were four estimations of span for each task and these were used to estimate reliability (this method is similar to that used by Engle, Tuholski, Laughlin & Conway, 1999; see also Henry, 2001). The correlations between the four span estimations were averaged to provide reliability estimates as follows: control picture span = .89 (range .83 - .94); phonologically similar picture span = .79 (range .67 - .89); visually similar picture span = .89 (range .82 - .94); and long word picture span = .80 (range .60 - .92). All of the span measures were reliable, with no single estimate below a moderately reliable level. In order to check for reliability of scoring within groups, the procedure was carried out separately for each participant group. The overwhelming majority of correlations were highly significant; only 4 relationships out of 72 were not significant, two in each of the MA and CA groups. Therefore, the scoring was reliable for all participants, even those with lower span scores (the MA and ID groups).

Results

Mean picture memory spans for the three groups are given in Figure 2 (error bars represent +/- 1 one standard error of the mean). A two-factor mixed analysis of variance with the repeated factor of picture type (4) and the between participants factor of group (3) revealed a significant main effect of group, F (2, 95) = 57.20, $p < .001$, partial eta squared (η^2) = .546. Post hoc Scheffe tests indicated that those in the CA group had higher picture spans (mean = 3.72) than those in either the MA or ID groups ($p < .001$); but that the MA (mean = 2.00) and ID (mean = 1.94) groups did not differ. There was also a main effect of picture type, F (2.80, 265.57) = 9.35, $p < .001$, $\eta^2 = .090$ (Huynh-Feldt correction for violation of sphericity as recommended by Field, 2005). Planned contrasts tested for the hypothesised effects of word length, visual similarity and phonological similarity by examining only the specific comparisons of interest to the study hypotheses; namely, performance on control items was compared to performance on each of the other three picture types. Across participant groups, there was a phonological similarity effect (F (1,95) = 22.66, $p < .001$, $\eta^2 = .193$), a visual similarity effect (F (1,95) = 6.93, $p < .05$, $\eta^2 = .068$) and a word length effect (F (1,95) = 23.06, $p < .001$, $\eta^2 = .195$).

However, of particular interest was whether different short-term memory codes were used by children within each experimental group. This was examined by looking at the interaction between picture type and group. This interaction was significant, F (5.59, 265.57) = 4.36, $p < .001$, $\eta^2 = .084$ (Huynh-Feldt correction). To explore the differences in recall between different picture types, and, hence, memory coding, in more detail, separate one-way repeated measures analyses of variance were performed on the picture memory scores for each group separately.

For children with ID and children in the MA comparison group, the effect of picture type was not significant. For children in the CA group, there was a highly significant effect of picture type, F(3, 93) = 9.83, $p < .001$, $\eta^2 = .241$. Planned contrasts, testing only the comparisons relevant for the study hypotheses, revealed a phonological similarity effect (F(1,31) = 18.73, $p < .001$, $\eta^2 = .377$); and a word length effect (F(1,31) = 21.52, $p < .001$, $\eta^2 = .410$); but no visual similarity effect.

Figure 2 about here

Analyses by Mental Age

It was predicted that children in the MA and ID groups would show visual similarity effects; in fact, no effects were found. However, it is possible that the groups encompassed children at a number of stages of development, masking potential effects. The final analyses looked in more detail at the MA and ID groups, testing whether any emerging effects of visual similarity, phonological similarity or word length might relate more specifically to mental age: i.e. lower mental age children might be at a less advanced stage of memory coding than higher mental age children. Children in both groups were classified as having a “high” mental age if they obtained mental age levels of 6 years 0 months or above on the BAS II nonverbal reasoning measure, based on the literature showing that a major stage transition towards verbal coding occurs at 6 years (Palmer, 2000). There were 10 “high” mental age children in the MA group (mean mental age 7;3) and 12 in the ID group (mean mental age 7;11). The remaining 20 children from the MA group and 24 children from the ID group were classified as having “low” mental ages, below 6 years 0 months (mean mental ages respectively were 5;5 and 4;9). Mean picture span scores for each mental age group are given in Figure 3.

A group (ID, MA) x mental age level (high, low) x picture type (control, phonological, visual, long) mixed analysis of variance revealed a significant effect of mental age level, F (1,62) = 16.34, $p < .001$, $\eta^2 = .209$, indicating higher spans for those with higher mental age levels, as would be expected (see Figure 3). There was an interaction between mental age level and group, F(1,62) = 7.68, $p < .01$, $\eta^2 = .110$, reflecting a larger mental age difference in span level within the ID group as opposed to the MA group (mean spans ID: high = 2.77, low = 1.53; mean spans MA: high = 2.15; low = 1.92). [Note this mirrored the larger MA difference between low and high mental age individuals in the ID group]. The effect of group was not significant; nor was the three-way interaction between picture type, group and mental age level.

The effect of picture type was significant, F (2.93, 181.39) = 3.82, $p < .05$, $\eta^2 = .058$ (Huynh-Feldt correction), but was qualified by a significant interaction between picture type and mental age level, F (2.93, 181.39) = 3.03, $p < .05$, $\eta^2 = .047$ (Huynh-Feldt correction). Separate one-way anovas confirmed a significant effect of picture type in the high mental age group, F (3, 129) = 2.98, $p < .05$, $\eta^2 = .124$, but not in the low mental age group (F=1.05). Planned contrasts on only the relevant comparisons for our study hypotheses in the high mental age group indicated a significant visual similarity effect, F (1,21) = 6.60, $p = .018$, $\eta^2 = .239$, a significant word length effect, F (1,21) = 8.09, $p < .01$, $\eta^2 = .278$, but no phonological similarity effect.

Figure 3 about here

Discussion

The type of memory coding used by children with ID was examined using picture memory span tasks assessing effects of visual similarity, phonological similarity and word length. Importantly, the span tasks avoided verbal “contamination” by preventing verbal input during presentation (labelling by children was discouraged) and utilising a pointing response to avoid verbal output. In this way, any evidence of verbal coding could be ascribed to the participant, rather than the task requirements. Similarly, potential spatial cues were minimised by presenting all items in the same spatial location and then removing them, rather than presenting and then covering items in a left to right horizontal row as is often done (e.g. Hitch et al., 1988; 1989; Rosenquist et al., 2003). Stages of memory coding development were examined and included the "pre-memory" coding strategy stage, the "visual" coding stage, the "dual visual and verbal" coding stage (e.g. Brown, 1977; Hayes & Schulze, 1977; Hitch et al., 1988; 1989; Longoni & Scalisi, 1994; Palmer, 2000), and the most mature stage of "verbal" coding.

Children with ID showed no clear evidence as a group of using memory coding strategies, suggesting that they were at the "pre-coding" phase of development. In this respect, they resembled the MA comparison group (approximately 5 years old) both in terms of level of recall (there were no group differences in level of picture span performance) and in terms of their "flat" profile of performance across picture types. By contrast, the CA comparison group of typically-developing 10-year-old children showed clear effects of both phonological similarity and word length, supporting previous findings with 10 and 11-year-olds (Hitch et al., 1988; 1989; Longoni & Scalisi, 1994). These children were at the "verbal" coding stage, a developmental level sufficiently advanced to allow the translation of the pictures into names, storage in a phonological code, and the use of picture names for some form of verbal rehearsal or verbal repetition prior to or during recall. As the task presented no verbal information and required no verbal output at recall, the presence of phonological similarity and word length effects can be regarded as reflecting the deliberate use of a verbal memory coding strategy. Arguments remain over whether word length effects are pure reflections of verbal rehearsal (e.g. Cowan et al., 1992; Henry et al., 2000; Romani et al., 2005; Yuzawa, 2001), however, they are clearly indicative of some form of verbal coding, particularly under conditions of visual presentation and non-verbal recall as were used in the current study. Many would also claim that some form of preparation of the speech output plan, naming of individual items or verbal rehearsal of the speech output plan takes place for those showing word length effects with non-verbal recall methods (Henry, 1991).

Although, overall, children in the ID and MA groups appeared to use no memory coding strategies, the profile of performance for children in these groups was different when they were divided into “high” mental age (6 years and above) and “low” mental age (below 6 years) groups. This suggested that developments in memory coding strategies were linked with increases in mental age. The reason for examining more detailed changes within the MA and ID groups, based on mental age, related to cross-sectional and longitudinal findings by Palmer (2000) who provided evidence for developmental transitions from no strategy use below the age of 5 years, to visual encoding at about age 5 years, to dual visual and verbal encoding at around age 6-8 years. There was not enough data to do more than divide the sample into above and below mental age 6 years, a key cut-off point with respect to the development of verbal coding strategies.

Results from the combined MA and ID groups showed that those with mental ages below 6 years showed a flat profile of performance across picture types, suggestive of no strategy use. Those with mental ages over 6 years showed significant visual similarity effects and significant word length effects (see Figure 3), broadly consistent with dual coding as found by Palmer (2000). This small, but significant interaction between mental age and picture type is indicative of developmental progressions in memory coding within the MA and ID groups. Note that there was no main effect of group (span scores were equivalent between the two groups as already noted) and there were no interactions between picture type and ID status to suggest that patterns of performance differed in the ID and MA groups. Mental age appeared to be a more important determinant of memory coding stage than ID status. Nor was there any evidence for a discrete visual coding stage. There was not enough data to test this latter point thoroughly in the current study, although it should be pointed out that previous reports of visual similarity effects in 5-year-olds have used methods involving verbal recall and/or a left to right spatial array of face-down pictures after presentation. The spatial array method may encourage visual confusions if children are using the array as a “spatial cue” (looking at the spatial location of individual pictures and trying to visualise them). Here, visual coding had to be initiated without the aid of spatial location cues provided by an array of face down cards.

The results have been described as broadly consistent with dual visual and verbal coding for the higher mental age MA and ID children. The most straightforward evidence for dual coding, however, would have been to find both visual and phonological similarity effects (suggestive of visual and verbal coding), but no word length effect (suggestive of more advanced use of rehearsal-style strategies). Here, visual similarity and word length effects were found, but the phonological similarity effect was not significant. One explanation for the results is based on the assumption that the ID and MA children with mental ages over 6 were using a simple naming strategy, but not full verbal rehearsal. This assumption can be well justified from the literature on the development of verbal rehearsal strategies. Several authors have postulated an intermediate stage of simple item naming before the development of full cumulative verbal rehearsal that would occur at around the ages of 6-8 years (e.g. Gathercole & Hitch, 1993; Henry & Millar, 1993).

In the current picture span task, a child using simple naming may name each item once and then attempt to recall the series. Phonological similarity would have a detrimental effect to the extent that these named items become confused. However, a child using a naming *and* verbal rehearsal compounds the effect of phonological similarity with every repetition of the list, hence, producing a stronger similarity effect. Several authors have noted the possibility of a “double” effect of phonological similarity stemming from both the phonological store and the verbal rehearsal process (e.g. Henry & Millar, 1993; Hulme & Mackenzie, 1992; Rosenquist et al., 2003). The effect of phonological similarity has also been reported to increase with age in typically developing children, consistent with additional confusion as verbal rehearsal develops (Hulme & Tordoff, 1989). A compound process of confusion may also occur with long named items. The stage of simple naming may produce a moderate detrimental effect on recall, because long-named items take longer to name, but this effect could be accentuated if the participant also engages in cumulative verbal rehearsal of the list items. There is evidence that simple naming of items may be enough to produce a significant word length effect (Henry, 1991).

To explain the current results in our higher mental age MA and ID groups (absence of phonological similarity effect, presence of word length effect), one would have to assume that the initial detrimental effect of simple naming were stronger in the case of long words than in the case of phonologically similar words. On this basis, a small, but non-significant, effect of phonological similarity emerges, together with the larger, significant, effect of word length. By contrast, children in the CA group were 10 years old and had reached the stage of mature verbal strategy use, so showed robust effects of both phonological similarity and word length, hypothesised to derive from both naming items and repeating them in sequence either once or repeatedly as in cumulative verbal rehearsal. By this stage, there was no evidence for dual visual coding in the picture memory span task. In summary, it is proposed that children with mental ages of 6-8 years, regardless of ID status, were using a “dual” visual and verbal coding strategy whereby the verbal coding took the form of simple naming rather than full cumulative verbal rehearsal.

Although previous work with children with ID has not specifically compared visual and verbal coding, Rosenquist et al. (2003) found significant visual similarity effects in children with mild ID (mean mental age 8 years 1 month). This is consistent with current findings; here, the higher mental age group of children with ID showing visual similarity effects had an average mental age of 7 years 3 months. Nevertheless, the children with higher mental ages were also those with milder intellectual disabilities, so it may be that developmental progress through the phases of memory coding outlined earlier is constrained by overall intellectual development. Those with lower ability levels, i.e. moderate ID, may never reach the higher levels of both performance and strategy use. There is evidence that children with moderate ID obtain significantly lower levels of performance than those with mild ID on more demanding working memory tasks (Henry, 2001) and on eyewitness memory tasks (Henry & Gudjonsson, 2003); whereas those with mild and borderline ID can in some circumstances approach memory performance levels of typically-developing age-matched controls.

Palmer (2000) stresses that even when children move beyond the dual coding phase to exclusive verbal coding, they nevertheless return to visual codes or dual coding in certain circumstances. This conjecture is supported by other work. There is evidence for the use of dual codes in short-term storage for adults (Hue & Erickson, 1988) and for the use of visual coding when verbal coding is blocked in older children (Hitch et al., 1989) and adults (Logie et al., 2000; Walker et al., 1993). In fact, such evidence forms part of the rationale for Baddeley's (2000) inclusion of the episodic buffer as a new component in working memory, integrating material from different modalities.

The absence of evidence for strategy use in children with mental ages below 6 years may indicate that they were relying on semantic representations, an argument that has recently been put forward to explain the abolition of word length effects under articulatory suppression in adults (Romani et al., 2005). Rosenquist et al. (2003) also suggested that individuals with ID might use semantic coding to recall word lists; and Kittler et al. (2004) noted the enhanced use of semantic codes in individuals with Down syndrome. Clearly, some explanation must be put forward for the recall of around 2 items that was achieved by children who were apparently using no strategy. Further work could include items of semantic similarity to test this claim.

An alternative explanation for the absence of strategic evidence in lower scoring participants is that floor effects prevented them from showing significant effects. This possibility cannot be entirely discounted, although two arguments can be offered against it. First, children in this study with low spans could obtain scores ranging from 0 through to 0.5, 1, 1.5 and 2. Thus, although low MA participants obtained mean scores of around 1.75, there was room for variation below this. Secondly, previous studies have reported significant visual similarity effects with performance levels in control and visually similar span tasks respectively of 1.9 versus 1.41 (Hitch et al., 1989), 2.07 versus 1.40 (Hitch et al., 1988) and 2.37 versus 2.05 (Palmer, 2000; although 3-year-olds showed no effects with mean performance of around 1.75). The only cautionary note is that these studies used fixed span lists of three items with verbal recall rather than a span procedure with non-verbal recall as was used here, so results may differ for this reason. It is possible that confusions only develop at longer list lengths when more items are competing with each other, although one would assume that the current response method (using response boards with 9 pictures to choose from) would have produced confusions at the recall stage. Further work could investigate this issue by contrasting fixed span lists and span procedures using otherwise similar methodologies.

In conclusion, 10-year-old children with ID were much like younger typical children of comparable mental age (5 years) with respect to their level of recall and use of memory coding strategies in a picture memory span task. Those with lower mental ages remained at the initial “pre-strategy” development stage and did not utilise memory coding strategies. The evidence was broadly consistent with the view that those in the MA and ID groups with higher mental ages (over 6 years) adopted a developmentally intermediate “dual” visual and verbal coding strategy. Older control children (10-year-olds) showed the expected, developmentally mature, effects of phonological similarity and word length indicative of verbal coding and some form of verbal rehearsal or verbal recitation of the list items.

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Table 1 Details of participants including age, mental age, estimated non-verbal I.Q., and raw ability score (pattern construction sub-test, BAS II) for children with ID, children of similar mental age (MA) and children of similar chronological age (CA). Standard deviations are given in brackets.

	Groups		
Participant details	Children with ID (n=36)	MA Controls (n=30)	CA Controls (n=32)
Chronological Age	10 yrs 6 m	5 years 1 m	10 years 0 m
(s.d.)	(20 m)	(4.5 m)	(13 m)
Mental Age	5 yrs 10 m	6 years 0 m	10 years 9 m
(s.d.)	(21 m)	(14 m)	(18 m)
Non-verbal I.Q.	60.94	113.67	105.81
(s.d.)	(12.58)	(11.86)	(10.82)
Raw Ability Score	91.72	100.30	137.34
(s.d.)	(24.62)	(12.72)	(11.07)

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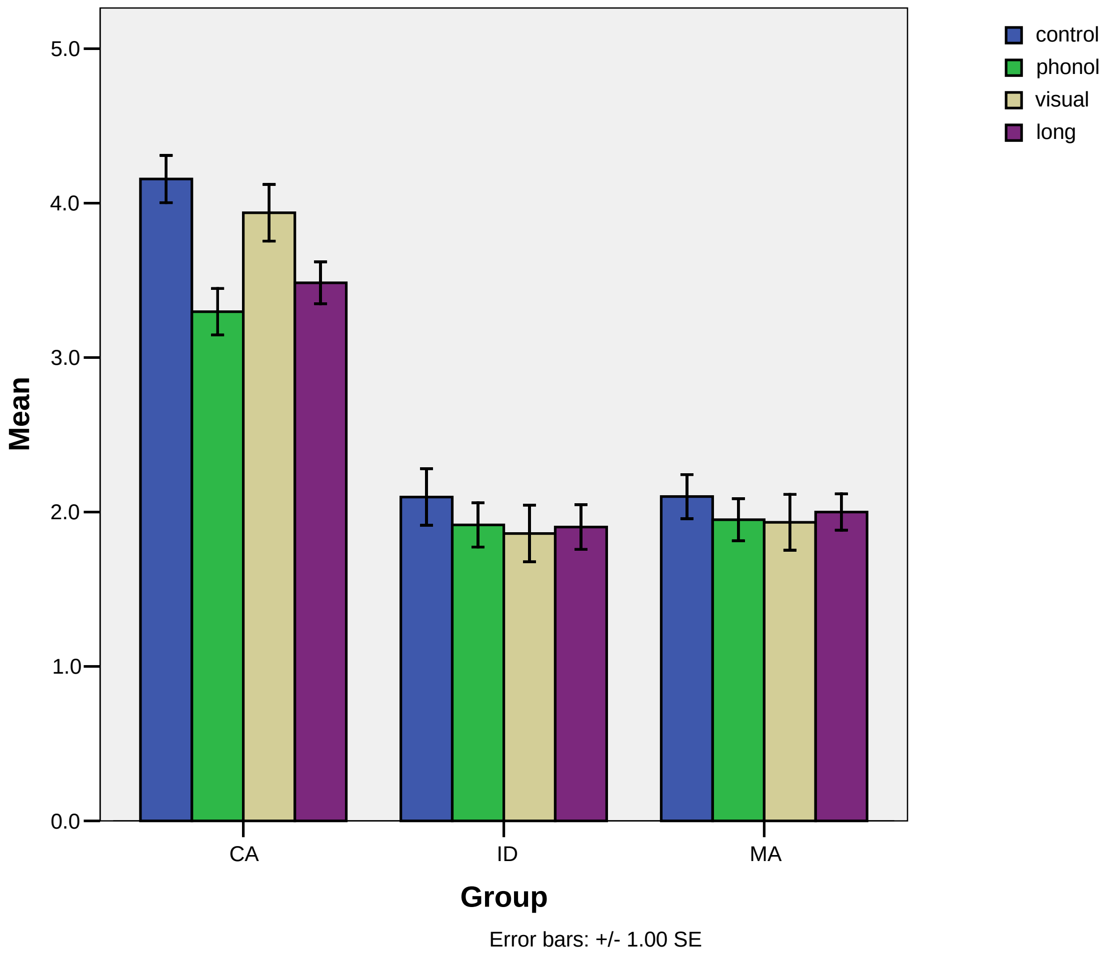
Captions

Figure 1 Examples of pictures from the control, phonologically similar, visually similar and long-named sets

Figure 2 Mean Memory spans for control, phonologically similar, visually similar and long-named pictures for children with ID, MA controls and CA controls

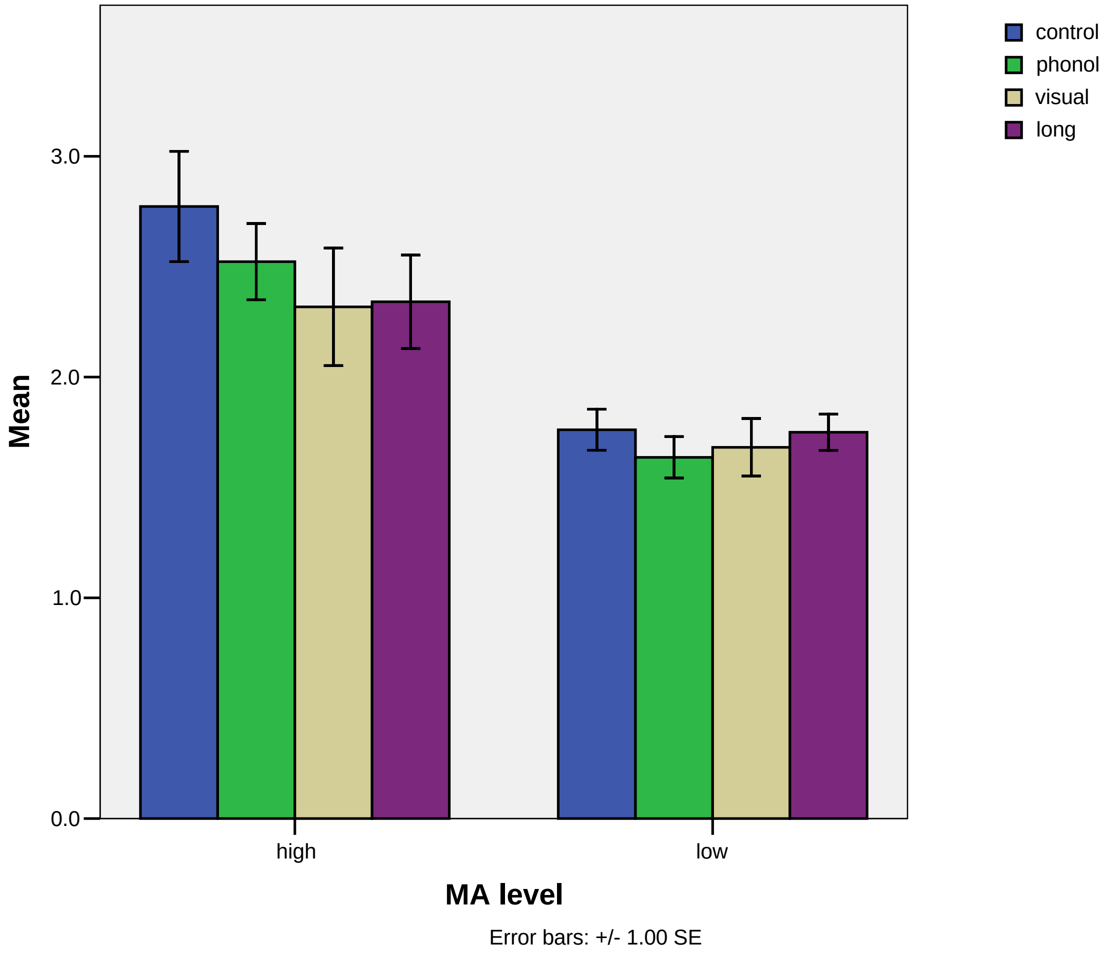
Figure 3 Mean Memory spans for control, phonologically similar, visually similar and long-named pictures for children in the ID and MA groups with “high” (6;0 and above) mental age versus “low” (< 6:0) mental age

Figure 2



Error bars: +/- 1.00 SE

Figure 3


Mean
3.0
2.0
1.0
0.0
high
low
MA level
Error bars: +/- 1.00 SE
control
phonol
visual
long