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Colour as an environmental cue when learning a route in a virtual environment; typical and atypical development

Emily K. Farran[1]

Yannick Courbois[2]

Jo Van Herwegen[3]

Alice G. Cruickshank[4]

Mark Blades[5]

[1]Department of Psychology and Human Development, Institute of Education, University of London

[2]Laboratoire PSITEC, Université Lille Nord de France

[3]Department of Psychology, Kingston University

[4]Department of Psychology, University of York

[5]Department of Psychology, University of Sheffield

Address correspondence to:

Emily K. Farran

Department of Psychology and Human Development

Institute of Education

25 Woburn Square

London WC1H 0AA

Tel: +44(0)207 6126272

E-mail: E.Farran@ioe.ac.uk

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Abstract

Typically developing (TD) 6-year-olds and 9-year-olds, and older children and adults with Williams syndrome (WS) navigated through brick-wall mazes in a virtual environment. Participants were shown a route through three mazes, each with 6 turns. In each maze the floor of each path section was a different colour such that colour acted as an environmental cue. The colours employed were either easy to verbalise (focal colours) or difficult to verbalise (non-focal colours). We investigated whether participants would verbally code the colour information in the focal colour condition only, and whether this facilitated route-learning. All groups could learn the routes; the WS group required more learning trials to learn the route and achieved lower memory scores than both of the TD groups. Despite this, all groups showed the same pattern of results. There was no effect of condition on the ability to learn the maze. However, when asked which colours featured in each route, higher memory scores were achieved for the focal colour (verbalisable) than the non-focal colour (non-verbalisable) condition. This suggests that, in both young children and individuals with WS, once a route has been learnt, the nature of the environmental cues within it can impact an individual’s representation of that route.

Keywords

Williams syndrome, Route learning, Wayfinding, Colour perception, Visuo-spatial cognition.

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This study investigated the use of verbal encoding as a strategy for learning a route in typically developing (TD) children and in individuals with Williams syndrome (WS). We aimed to determine empirically whether the transition from visual encoding of visual information to verbal encoding of visual information observed in TD children in the working memory literature (e.g. Baddeley, Gathercole & Papagno, 1998; Hitch, Woodin & Backer, 1989) extends to route-learning. We were also interested in whether individuals with WS have the ability to spontaneously verbally encode visually presented information when learning a route. WS is a genetic disorder with a prevalence of 1 in 20,000 that is characterised by a cognitive profile in which visuo-spatial abilities are impaired relative to verbal abilities (e.g. Mervis, Morris, Bertrand & Robinson, 1999). Given this cognitive profile, a verbal encoding strategy could be particularly beneficial for this group.

Route-learning

Siegel and White (1975) posit that a cognitive representation of an environment develops in sequence starting with knowledge of the landmarks along a specific route (landmark knowledge), followed by knowledge of the sequential order of the turns and landmarks of that route (route knowledge). The final stage, which is arguably qualitatively different from the first two stages (Montello, 1998), involves developing knowledge of the configurational structure of an environment (configurational knowledge), also known as the ability to use a cognitive map.

Whilst configurational knowledge enables flexible navigation (e.g. taking short-cuts), it is still possible to find your way based on landmark and route knowledge alone, so long as learnt routes can be followed. Baldwin and Reagan (2009) suggest that, in adulthood, landmark and route knowledge can be differentiated from configurational knowledge in relation to contributions from verbal and visuo-spatial ability. They observed that adults who achieved low scores on the Sense-Of-Direction (SOD) self-report questionnaire (Kato & Takeuchi, 2003), which is indicative of a heavy reliance on landmark and route knowledge when navigating, showed greater interference from a concurrent verbal task than a concurrent visuo-spatial task. The opposite pattern was observed for adults with a greater reliance on configurational knowledge (high SOD scores). This suggests that verbal encoding is a particularly useful strategy for developing good landmark and route knowledge, whilst configurational knowledge is best represented non-verbally. In the current study, we explored landmark and route knowledge only, to determine how verbal encoding of this information develops. Investigation of landmark and route knowledge is also timely as these types of spatial knowledge have received limited attention (see Buchner & Jansen-Osmann, 2008), with most research on route-learning concentrating on configurational knowledge.

The development of verbal encoding

Drawing from the Developmental Psychology literature, Bruner (1966) suggested that children move from the iconic stage of representation, which involves representing images visually, to a symbolic stage of representation at about 6 years, in which visual information can be represented verbally. This is supported by investigation of the development of working memory which has shown, using lists of line drawings and pictures, that younger children rehearse and store information visually, with the ability to verbally rehearse information coming on-line at approximately 7 years (e.g. Baddeley et al., 1998; Hitch et al., 1989). The development of the use of verbal coding has received minimal attention within the route learning literature. Cornell and Heth (2006) discuss verbal mediation as a possible strategy for learning landmarks within an environment. Anecdotally, they state that from 10 years, TD children begin to verbally label landmarks and use the linguistic information on landmarks such as street signs. The ability to learn a route represents a real-world application in which verbal encoding of landmarks, cues, and turns within the visual array might be a useful strategy to facilitate successful navigation.

The influence of environmental cues when learning a route

When exploring a new environment, factors in that environment provide cues which influence route-learning. In a natural environment, landmarks such as a distinctive building or a tall tree provide perceptually salient cues and can be used as beacons or reference points (Waller & Lippa, 2007). Other cues such as colour, particularly in man-made environments like buildings, can also be useful (Evans, Fellows, Zorn & Doty, 1980; Jansen-Osmann & Wiedenbauer, 2004).

We used colour as an environmental cue in the present study, because colours are salient visual cues which can be categorised into focal and non-focal colours (Ling & Blades, 2002). Focal colours are ones that are easy to verbalise (e.g. red, blue, green, yellow) and non-focal colours are ones that are difficult to verbalise (e.g. a murky yellow or mixture between purple and grey), thus colour is an ideal medium by which to assess the use of verbal encoding. The English language includes eleven basic colour categories (Berlin & Kay, 1969). Category prototypes (focal colours) are easy to name. If one imagines colours plotted spatially (colour space), non-focal colours are perceptually distant from focal colours; for adults, the further away a non-focal colour is from any focal colours within colour space (i.e. the more a non-focal colour is dissimilar from any of the eleven basic colour categories), the more difficult it is to name (Boynton & Olson, 1987; 1990). Laws (2002) demonstrated, in a working memory task, that TD children aged 3 to 7 years showed an advantage in remembering a sequence of focal colours over a sequence of non-focal colours. This suggests that TD children make use of verbal encoding when presented with colours that are easy to verbalise.

A second reason for using colour is that it is a useful cue to route-learning for both children and adults. To our knowledge, within the route-learning literature, only two studies have hitherto explored the use of colour cues. Evans et al. (1980) gave adult participants a tour of a university building. For half of the participants, the building had been colour-coded with focal colours. They demonstrated an advantage of the colour-coded condition when participants were asked to find the shortest route to locations in the building, and in participants' recall and recognition of floor plans of the building. Jansen-Osmann and Wiedenbauer (2004) explored the use of colour-coding developmentally. Participants freely explored a virtual environment, in which the floors were either all grey or colour-coded, such that the environment was partitioned into three different focal-coloured areas. They reported that 8- and 12-year-old children and adults, were all positively influenced by colour to a similar extent when asked to find the shortest route to a target location.

Both Evans et al. (1980) and Jansen-Osmann and Weidenbauer (2004) used focal colours, so participants may have verbalised the colour cues. If this is the case, it is noteworthy that Jansen-Osmann and Weidenbauer (2004) showed adult-like performance at about 8 years of age. In the present study we investigated 6-year-olds' and 9-year-olds' ability to learn a route with focal or non-focal cues to assess the development of verbal encoding

Route-learning in Williams syndrome

Route-learning is a relative weakness within the WS cognitive profile (Farran, Blades, Boucher & Tranter, 2010; Farran, Courbois, Van Herwegen & Blades, in press). Farran et al. (2010) explored the impact of the experimenter explicitly verbally labelling the landmarks and turns when demonstrating a real-world 1- kilometre route to participants. Older children and adults with WS, as well as participants with moderate learning difficulties (matched for non-verbal IQ and chronological age) and chronological-age-matched TD participants, showed improved route knowledge when landmarks and turns along the route were verbalised, relative to a non-labelling condition. In contrast, in Farran et al. (in press) routes were presented within a virtual environment. A similar comparison was made between labelling and non-labelling conditions, but verbal labelling was not advantageous to older children and adults with WS or to TD children aged 6, 7, 8, and 9 years.

The real-world environment and the virtual environment used in these two studies differed substantially in terms of the richness of environmental cues. This could explain the different effects of verbal labelling. In a real-world environment, one is bombarded with visual stimuli, which vary in their salience and usefulness as cues to route-learning. One possibility is that verbal labelling in the real-world study facilitated performance because it acted to select an appropriate subset of salient landmarks, i.e. highlighting the salient information to participants, thus reducing the cognitive load and facilitating route-learning. In the virtual environment, by design, the environment was sparse with just 16 landmarks, and the landmarks were all verbalisable objects, equally salient and strategically placed (an advantage of using a virtual environment over a real-world environment). It is possible that in the virtual environment, participants spontaneously attended to each landmark and that the lack of advantage of labelling over non-labelling conditions indicated that participants applied a spontaneous verbal-coding strategy, even in the non-labelling condition. If individuals with WS do make use of verbal encoding of visual information spontaneously, this is clearly a useful strategy in which their relative strength in verbal abilities is being used to bolster their relative weakness in visuo-spatial abilities. Indeed, correlational evidence across IQ subtests suggests that this might be the case (Farran, Jarrold & Gathercole, 1999).

The current study

The current study used a similarly sparse virtual environment as used in Farran et al. (in press) to determine whether individuals with WS and TD children can use verbal encoding spontaneously, provided that the cognitive requirements of the task are relatively low. We measured participants' ability to learn a route and, once a route had been learnt, their memory for the colours that featured on that route. The TD children included 6-year-olds and TD 9-year-olds, chosen to be on either side of the shift from a visual to a verbal encoding strategy as documented by the working memory literature (Baddeley et al., 1998). By using a virtual environment we could ask participants to retrace a route numerous times, we could control for landmark salience and we could strategically manipulate differences and similarities across different virtual environments. In this study, this enabled us to identify the contribution of verbal encoding to landmark and route knowledge unambiguously.

We measured landmark and route knowledge only, as these aspects of spatial knowledge are associated with verbal strategy use in adults (Baldwin & Reagan, 2009). We hypothesised that the following. 1) If verbal encoding was available to participants then there would be an advantage of the focal condition over the non-focal condition. 2) The 9-year-olds, but not the 6-year-olds, would show evidence of verbal encoding. 3) The WS group would show facilitation in the focal condition and that this would indicate that verbal mediation is an effective strategy during route-learning for this group.

Memory for the colours that featured on each route was measured using verbal recall and visual recognition (colours were presented as coloured tiles). We further hypothesised that: 4) Overall, visual recognition would be stronger than verbal recall (Ling & Blades, 2000), but that this might interact with verbal or non-verbal encoding strategies, i.e. the effect would be weaker when verbal encoding was employed to learn the route.

Method

Participants

Nineteen older children and adults with WS took part, fourteen of whom completed the task. Five participants did not complete the task due to illness (N=3), unwillingness to continue (N=1) or time constraints (N=1). WS participants were recruited from the records of the Williams Syndrome Foundation, UK and had received a positive diagnosis of WS based on phenotypic and genetic information. Genetic diagnosis was based on a Fluorescent insitu Hybridisation (FISH) test (see Lenhoff, Wang, Greenberg & Bellugi, 1997). The TD children included two groups who attended UK primary schools in Year 1 and in Year 4. These year groups are the academic years in which children have the 6th and 9th birthday respectively, and so have been labelled as TD 6-year-olds and TD 9-year-olds respectively (N= 20 per group). Verbal ability was measured using the British Picture Vocabulary Scale II (Dunn, Dunn, Whetton & Burley, 1997) and visuo-spatial ability was measure using the Raven’s Coloured Progressive Matrices (RCPM: Raven, 1993). Whilst the WS group had a higher Chronological Age than the two TD groups, Chronological Age is typically unrelated to visuo-spatial performance in WS (see Atkinson et al., 2001). We considered that the TD groups were suitable comparison groups to the WS group because the route learning task is a visuo-spatial task, and the WS group did not differ statistically in visuo-spatial ability (RCPM score) from either of the TD groups ($p>.05$ for both comparisons). Participant details are displayed in Table 1.

Table 1 about here

Design and Procedure

Each Virtual Environment (VE), programmed in Vizard (www.Worldviz.com) was a 3D maze of brick walls (see Figure 1 for screenshots of a maze). VEs were presented on a 40-inch screen at a viewing distance of 50cm, and participants navigated using a joystick. Participants first used the joystick to navigate around a practice maze which had a similar structure to the experimental mazes. Each maze had six junctions. At each junction there were two possible path sections that the participant could choose to take; one was a correct path section and led to the next junction (or, from the final junction, the end of the route), and the other was an incorrect path section and led to a dead-end. From a first person perspective, each correct route consisted of two left, two right and two straight ahead turns across the six junctions. Incorrect path sections were similarly distributed (two left, two right and two straight ahead turns).

For each maze, the participant used a joystick to walk along the path sections. The initial path section had a dark grey floor and led to the first junction, after which the floor of each of the remaining twelve path sections (six on the correct route and six incorrect) was a different colour. The coloured path sections acted as environmental cues. There were two conditions. In the focal colour condition, the twelve path sections were the 11 focal colours, as listed in Table 2, and turquoise.

These colours are comprehended by TD children by the age of 4 years (Pitchford & Mullen, 2002). In the non-focal colour condition, the twelve path sections were 12 non-focal colours, also listed in Table 2. These were created by averaging across the red, green and blue contributions of focal colours to create non-focal colours that were maximally dissimilar from any focal colours. The details of the colours used are shown in Table 2. Focal and non-focal colour conditions were counterbalanced. The focal condition could be encoded non-verbally or verbally, whilst the non-focal condition was more conducive to non-verbal, than verbal encoding.

To ensure that any effect of focal versus non-focal conditions was not related to a specific route design, two mazes were created for each condition (2 focal colour mazes and 2 non-focal colour mazes; 4 mazes in total) and participants received one of two mazes for each condition. For each condition (focal colour condition and non-focal colour condition), participants were shown the correct route through the maze by the experimenter who walked through the maze using the joystick. The correct route in each condition consisted of six turns. The learning phase then commenced, in which participants were instructed to use the joystick to walk their way along the correct route from the entrance of the maze to the exit. Participants completed as many learning trials as were needed for them to meet the criterion of two consecutive successful completions of the correct route without any errors. An error was record if a participant turned to look down an incorrect path section, or travelled down an incorrect path section. Participants walked the route again to the same criterion between the two colour memory phases (described below).

In the visual response and verbal response colour memory phases (counterbalanced), all path sections were the same dark grey colour. The experimenter navigated the correct route using the joystick, and stopped at the beginning of each correct path section. In the visual response test phase participants were asked to remember the original colour of that path section by pointing to the appropriate colour on a response array of 12 colour tiles which showed the 12 colours that had featured in that condition. In the verbal response test phase, participants were asked to remember the original colour of that path section by verbally naming the appropriate colour.

After the testing session (for both focal and non-focal conditions), participants took part in a focal colour naming task and a non-focal colour naming task (counterbalanced). In the focal colour naming task participants were shown 12 colour tiles of the focal colours and asked to name the tiles. This was to verify that all participants knew all of the focal colours and their names. In the non-focal colour naming task participants were shown 12 colour tiles of the non-focal colours and asked to name them. The names given were used by the experimenter when coding the data from the colour memory phase, to determine correspondence between the colours and the names that each participant used in the verbal response colour memory phase.

Table 2 and Figure 1 about here

Results

Learning phase

Two dependent variables were used: the number of learning trials required to meet criteria (including the two error-free criterion trials) and the cumulative number of errors made across those learning trials (if a participant turned to look down, or walked down an incorrect path section, this was recorded as an error). Patterns of performance for these two variables are shown in Figures 2 and 3.

Number of learning trials: ANOVA was carried out with condition (focal colour, non-focal colour) as a within-participants factor and group (TD 6 years, TD 9 years, WS) as a between-participants factor. A main effect of group, F(2, 51)=6.07, p=.004, $ŋ_p^2$ = .19, revealed that the WS group required more learning trials than either of the TD groups (p<.05 for both), with similar performance from the TD 6-year-olds and TD 9-year-olds (p=.91). There was no main effect of condition, F<1, or interaction between condition and group, F<1.

Number of errors: ANOVA was carried out with condition (focal colour, non-focal colour) as a within-participants factor and group (TD 6 years, TD 9 years, WS) as a between-participants factor. The pattern of results was very similar to the analysis above. There was a main effect of group, F(2, 51)=5.24, p=.009, $ŋ_p^2$ = .17. The WS made significantly more errors than the TD 9-year-olds (p=.007), but not the TD 6-year-olds (p=.067). There was no significant difference between the errors made by the two TD groups (p=.577). There was no main effect of condition, F<1, or interaction between condition and group, F<1.

Figures 2 and 3 about here

Colour memory phase

The number of correctly recalled colours was recorded. For the visual response test phase participants responded by pointing to a colour. For the verbal response test phase participants responded by verbalising a colour. If participants gave a ‘don’t know’ response, they were further encouraged to give a response. If a response was still not elicited, a ‘don’t know’ response was coded as an error. Participants found it difficult to give names for non-focal colours. Terms such as “sort of pink, but not really” or “a toothpaste colour” were used. As such, we used the name that the participant subsequently gave in the non-focal naming task (conducted at the end of the testing session) to score their response in the verbal response test phase of the non-focal condition. However, children were not always consistent in the label used. In other words, there was some subjectivity in the coding and so the responses of 10% of participants in each group were chosen at random and coded by a second rater. This produced high inter-rater reliability, Kappa = 0.87, $p<.001$.

ANOVA was carried out with condition (focal colour, non-focal colour) and response type (visual, verbal) as within-participant factors and group (TD 6 years, TD 9 years, WS) as a between-participants factor (see Figure 4). A main effect of group, $F(2, 51)=13.25$, $p<.001$, $ŋ_p^2 = .34$, revealed that the WS group recalled fewer colours than either of the TD groups ($p<.05$ for both), with similar performance in the TD 6-year-olds and TD 9-year-olds ($p=.15$). There was a main effect of condition, $F(1, 51)=21.18$, $p<.001$, $ŋ_p^2=.29$, due to better recall of focal than non-focal colours. There was also a main effect of response type, $F(1, 51)=8.75$, $p=.005$, $ŋ_p^2=.15$, because verbal recall was better than visual recall. All interactions were non-significant: Condition x Response type, $F(1, 51)=1.56$, $p=.22$, $ŋ_p^2=.03$; for all other interactions, $F<1$.

Figure 4 about here

Discussion

Individuals with WS are able to learn a route to 100% accuracy. This is consistent with Farran et al. (in press) and is impressive given their other weaknesses in visuo-spatial cognition. The WS group showed the same pattern of performance as the TD children, which further suggests that they completed the task in a typical manner. For all three groups, performance in the focal colour condition had an advantage over the non-focal colour condition when recalling the colours in the colour memory phase, but not whilst learning the route during the learning phase. During the learning phase, performance was equivalent across focal and non-focal conditions.

The results indicate that individuals with WS, TD 6-year-olds and TD 9-year-olds can spontaneously use verbal encoding of non-verbal information, and that this benefits their explicit knowledge of an environment. It is notable that there was no focal condition advantage during the learning phase across the groups. This could suggest that encoding style, verbal or non-verbal, impacts knowledge of the environment, but not the ability to learn that environment. We cannot rule out, however, that the routes were learnt in a comparable manner in the focal and non-focal conditions (e.g. non-verbally encoding the colours, or simply remembering a series of turns), and that in the subsequent colour memory phase participants used mental imagery to recall the route and applied verbal encoding at this stage, i.e. they verbally encoded their mental image of the colours, thus eliciting the focal colour advantage observed in the colour memory phase. Further exploration of route-learning strategies when learning a route would be required to fully interpret the pattern of results observed in the learning phase. Despite this, it is clear that verbal encoding of an environment has substantial benefits on participants’ explicit knowledge of the environment.

With reference to the WS group, the current finding supports the suggestion in Farran et al. (in press) that the lack of a positive effect of verbal cueing reflects that the WS participants in that study were already using verbal encoding. This also suggests that, dependent on the demands of the task, individuals with WS can learn to use their cognitive strengths to bolster their cognitive weaknesses. This has implications for syndrome-specific training on tasks that call on areas of visuo-spatial cognition, i.e., when verbal encoding can be implemented, this compensatory strategy should be encouraged in WS. For example, people with WS could be encouraged to verbalise what they are seeing as they walk around real-world environments.

With reference to the TD participants, we have shown a benefit of verbalisable colour-cues for explicit knowledge of an environment from as young as 6 years. Two previous studies have explored the use of colour as an environmental cue to route-learning (Evans et al., 1980; Jansen-Osmann & Wiedenbauer, 2004). These studies demonstrated an advantage of focal colour-cues over no colour-cues. Both studies reported a benefit when participants were asked to identify the shortest route to a place in the environment, and Evans et al. (1980) additionally demonstrated an advantage in recall and recognition of the configuration of the environment. Thus these two studies demonstrated that the use of colour-cues has a positive impact on knowledge of an environment. Our study asked the more subtle question of *why* colour is an effective cue to route-learning. We demonstrated that colour-cues have a stronger impact on explicit knowledge of the environment if they can be easily named, and that this effect is evident from at least 6 years. This implies that the participants in Evans et al. (1980) and Jansen-Osmann and Wiedenbauer (2004) were also verbally encoding the colour-cues provided.

We found no differences between TD 6-year-olds and TD 9-year-olds for accuracy or patterns of performance. This suggests that the verbal encoding strategy employed at 9 years is in place by at least 6 years in typical development. The working memory literature posits that the shift from visual to verbal encoding of stimuli such as line drawings occurs at approximately 7 years (e.g. Baddeley et al., 1998). Laws (2002) demonstrated an advantage of memory for focal over non-focal colours in a working memory task from as early as 3 years. Laws (2002) suggested that whether participants can apply verbal encoding is dependent on the nature of the stimuli and the task design, and that it is possible that, for younger children, colours can be verbally encoded more easily than the line drawings of objects that are often used in working memory studies of verbal re-coding. In support of this, research has shown that the colours of objects that children have been interacting with are incidentally encoded from at least 4 years (Ling & Blades, 2002). Although a route-learning task differs substantially from a working memory task, and would not be within the range of abilities of a 3-year-old, perhaps we should not be surprised that the 6-year-olds in the current study showed evidence of verbal encoding in the colour memory phase. In future research it would be interesting to explore route-learning in environments that use non-verbalisable versus verbalisable objects as landmarks. If verbal encoding occurs later in development for objects than for colours, this would have implications for training route-learning skills. For example, when children start school, it might be useful for teachers to use coloured markers as environmental cues to aid orientation within the classroom environment or at junctions of corridors within the school.

Despite a similar pattern of performance across groups, the level of performance of the WS group was poorer than that of both TD groups. This was true of both the learning phase and the colour memory phase. In contrast, in Farran et al. (in press), a WS group performed below the level of TD 9-year-olds, but at a comparable level to TD 6-year-olds. The virtual environments used in that study were similar to the current virtual environments, but included landmarks as environmental cues rather than colour. A tentative suggestion is that young TD children benefit from colour cues to a greater extent than landmarks as environmental cues, whereas both cue-types are similarly beneficial for individuals with WS. Future research could directly compare the use of colour versus landmarks as environmental cues.

Although we predicted that responses in the visual response test phase would be strongest because this involved recognition rather than recall of colours (see Ling & Blades, 2000), for all three groups the opposite pattern was observed; performance was better in the verbal response test phase than in the visual response test phase. This suggest that when tested immediately after experiencing the colour-coded route, verbal representations are sufficiently strong to favour memory retrieval from the same domain (i.e. verbal responses). Furthermore, the advantage of the verbal response test phase did not interact with condition, and so the effect was consistent despite non-focal colours being difficult to verbalise. This suggests that although the non-focal colours were designed to be difficult to verbalise, participants had attempted to verbally encode these colours, but that their verbal representations were significantly weaker than those employed for the focal colours, as indicated by the main effect of condition in the colour memory phase. The lack of interaction between response type and condition also demonstrates that non-verbal encoding of focal colours was stronger than for non-focal colours. This suggests, in line with the working memory literature, that verbal encoding of non-verbal information is optimum, and that this is independent of the method of recall; the ease with which focal colours could be verbally labelled served to strengthen participants’ general representations of those colours with a positive impact on both verbal and visual recall.

In summary, the use of virtual environments has enabled us to conduct a carefully controlled investigation of the use of colour as an environmental cue to route-learning. Our results support previous studies which demonstrated the usefulness of colour cues for route-learning, and we have further demonstrated that young TD children and individuals with WS prefer to verbally encode non-verbal information when the stimuli allow. The young age at which TD children can use verbal encoding in this context is an important finding, given anecdotal reports that verbal encoding when navigating is not explicitly noted until children are 10 years old (Cornell & Heth, 2006). Furthermore, evidence of the use of verbal encoding in WS indicates that performance on visuo-spatial tasks can be improved in this group using verbal ability, a relative strength within the WS cognitive profile.

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Table 1:

Participant details: Chronological age (CA), British Picture Vocabulary Scale (BPVS) raw scores and Raven's Colored Progressive Matrices (RCPM) raw scores.

Group	CA (years; months)		RCPM score	BPVS score
	Mean (S.D.)	Range	Mean (S.D.)	Mean (S.D.)
TD 6 years (N=20)	6;00 (0;03)	5;07-6;04	16.40 (2.74)	56.05 (11.22)
TD 9 years (N=20)	8;09(0;03)	8;05-9;01	21.20(5.58)	74.55(11.90)
WS (N=14)	22; 05(8;11)	10;05-43;04	18.61(6.59)	97.00(25.13)

Table 2a.

Red, Green and Blue contributions (RGB values) to colours employed in the focal colour maze

	RGB values		
Colour	Red	Green	Blue
Red	255	0	0
Orange	255	125	0
Yellow	255	255	0
Green	0	255	0
Blue	0	0	255
Pink	255	0	255
Purple	99	0	166
Grey	192	192	192
Black	0	0	0
Brown	113	63	21
Turquoise	153	255	236
White	255	255	255

Table 2b.

Red, Green and Blue contributions (RGB values) to colours employed in the non-focal colour maze

	RGB values		
Colour	Red	Green	Blue
orange-pink	242.5	88	76.5
yellow-green	200	255	145
red-purple	140	0	67
green-blue	0	127.5	127.5
yellow brown	184	159	10.5
pink grey	211	121.5	172.5
blue yellow turquoise	136	170	163.667
red orange	255	171	145
purple grey	145.5	96	179
blue purple brown	52	71	108
grey orange	223.5	158.5	96
grey brown	210	199	190

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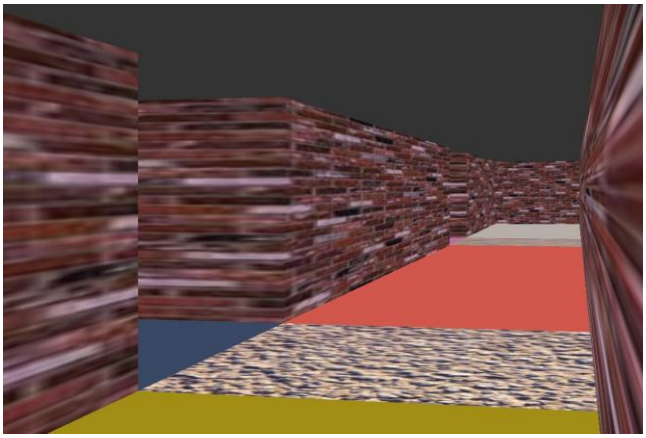

Figure 1a: A screenshot of the non-focal colour maze

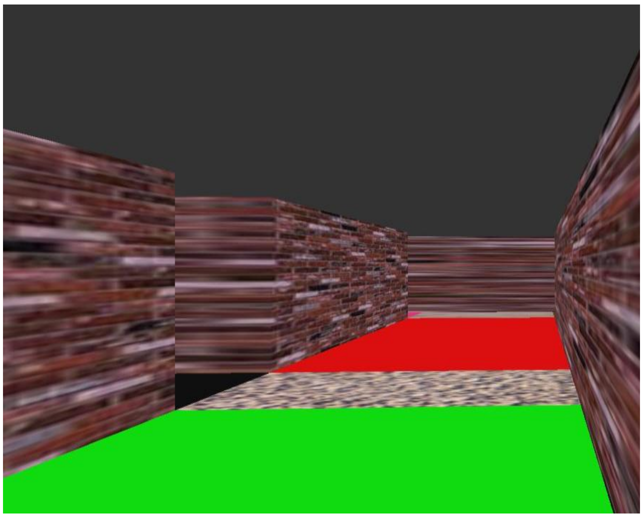

Figure 1b: A screenshot of the focal colour maze

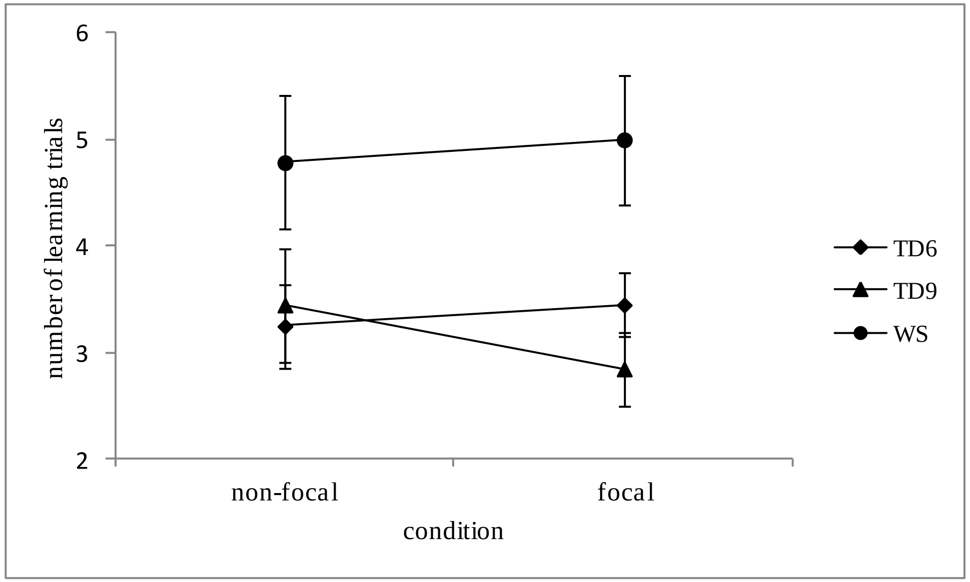

Figure 2. Mean number of learning trials (including the two error-free criterion trials) per condition. Error bars represent standard error.

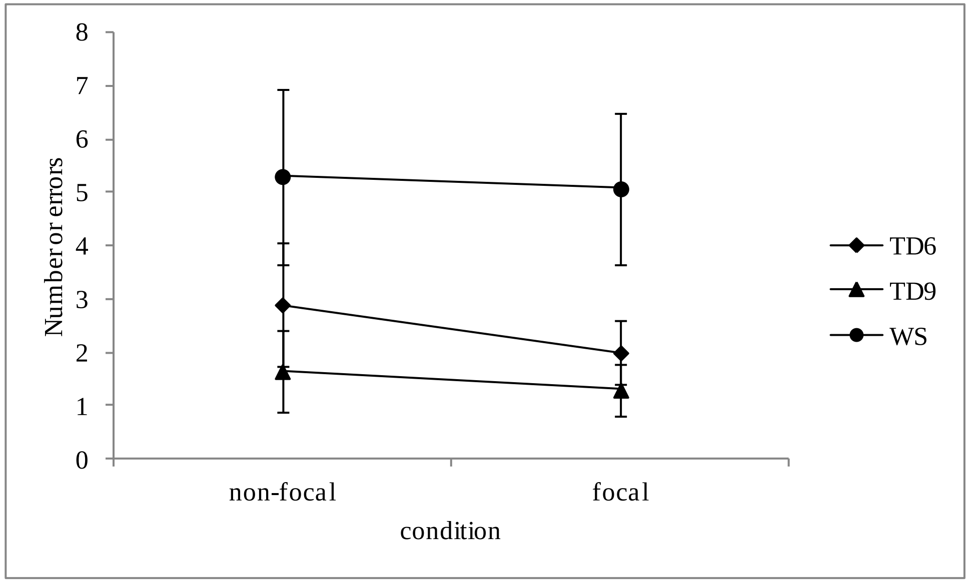

Figure 3: Mean number of errors made across learning trials per condition. Error bars represent standard error.

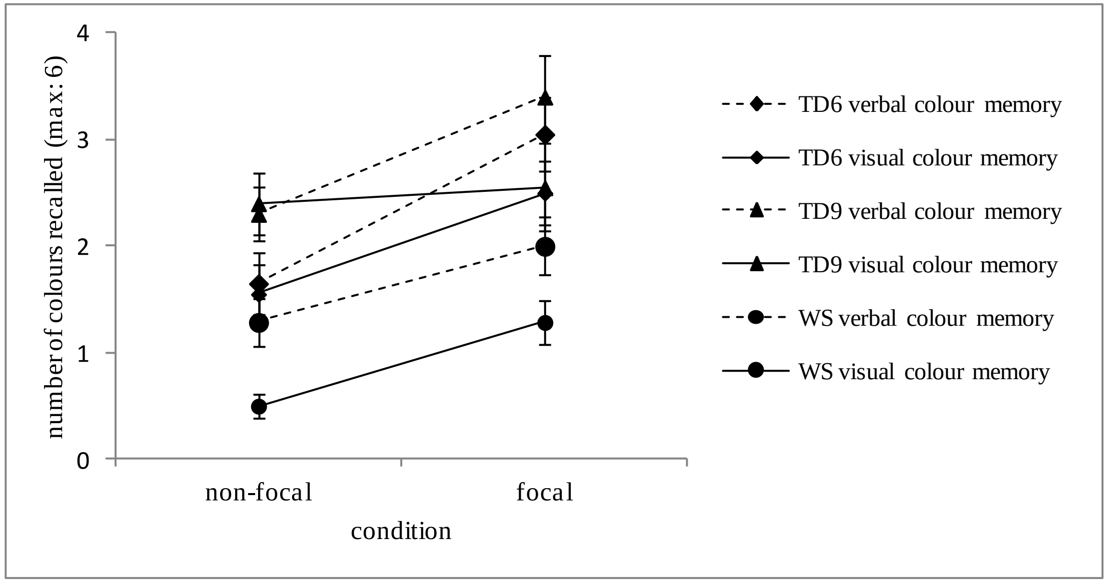

Figure 4: Mean number of colours recalled in the visual response and verbal response test phases for each condition. Error bars represent standard error.