How to learn places without spatial concepts: Does the what-and-where reaction time system in children regulate learning during stimulus repetition?

Christiane Lange-Küttner [a,*], Enno Küttner [b]

[a] *School of Psychology, London Metropolitan University, UK*
[b] *Achieving for Children (CIC), Emotional Mental Health Service for Kingston and Richmond, London, UK*

ABSTRACT

We investigated the role of repetition for place learning in children although the acquisition of organizing spatial concepts is often seen as more essential. In a reaction-time accuracy task, 7- and 9-year-old children were presented with a randomized sequence of objects-in-places. In a novelty condition (NC), memory sets in different colors were presented, while in a repetition condition (RC), the identical memory set was tested several times. Shape memory deteriorated more than place memory in the NC, but also stayed superior to place memory when both improved in the RC. False alarms occurred for objects and places in the same way in 7-year-olds in the NC, but were negligible for 9-year-olds. Incontrast, false alarms in the RC occurred in both age groups mainly for place memory. The Common Region Test (CRT) predicted reaction times only in the novelty condition, indicating use of spatial concepts. Importantly, reaction times for shapes were faster than for places at the beginning of the experiment but slowed down thereafter, while reaction times for places were slow at the beginning of the experiment but accelerated considerably thereafter. False alarms and regulation of reaction times indicated that repetition facilitated true abstraction of information leading to place learning without spatial concepts.

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1. Introduction

Young children can find just one object very exciting, hold it very close and do not monitor where the object was in an array (Smith, Yu, & Pereira, 2011). Like in emotion regulation in a social context (Carlson & Wang, 2007; Ochsner, Bunge, Gross, & Gabrieli, 2002), also in the individual visuo-perceptual experience, saliency of objects can be regulated. For instance, young children draw objects very large and small size occurs only because of lack of space on the page (Freeman, 1980; Thomas, 1995). But with the emergence of an explicit context of spatial axes and area boundaries, children learn to control and regulate size and can modify object or figure size from very large to extremely small (Lange-Küttner, 1997, 2004, 2009). The excitement that objects can elicit is still present in adults: Heart-beat evoked brain responses predict visual detection (Park, Correia, Ducorps, &

Tallon-Baudry, 2014) and paying attention to shapes enhances their perceived contrast and visibility (Liu, Abrams, & Carrasco, 2009). However, this salience of objects can distract from realizing where objects actually are (Ansorge, Priess, & Kerzel, 2013).

Shape and space processing takes place in the brain in the what-and-where system in the monkey (Mishkin, Ungerleider, & Macko, 1983) as well as in adult humans (Mecklinger & Meinshausen, 1998; Mecklinger & Müller, 1996). The current study investigates whether the what-and-where system in children is involved in visual memory. In particular, place learning (the where-system) posed a problem for children independently of their acceleration during the experiment, the type of spatial array and spatial grouping concepts (Lange-Küttner, 2013). Would repeated viewing of memory sets allow place learning to occur during the experiment, or would novel memory sets create a more exciting task that facilitates place memory? For instance, visual priming (fast mapping) can lift performance in a repeated session by about ten per cent (Lange-Küttner, 2010b). Moreover, young children can sketch in perspective years ahead before they can explain the geometrical principles of perspective when they see a model with built-in perspective and just need to repeat this visual

* Corresponding author at: London Metropolitan University, Faculty of Life Sciences and Computing, School of Psychology T6-20, 166-220 Holloway Road, London N7 8DB, UK. Fax: +44 2088081681.

E-mail address: c.langekuettner@londonmet.ac.uk (C. Lange-Küttner).

impression on their sheet of paper (Lange-Küttner, 2014a, 2014b). This result would not have been expected by accounts of a rather protracted conceptual development in children (e.g. Newcombe & Huttenlocher, 2003; Piaget & Inhelder, 1956) that assumes that more sophisticated representations in spatial cognition would only develop with age.

Thus in this study, it was assessed whether children can derive a benefit for their place learning from repeatedly seeing memory sets within one session. Computerized cognitive training of memory in children is currently investigated in several labs because it produces long-lasting enhanced cognition (Holmes, Gathercole, & Dunning, 2009; Jaeggi, Buschkuehl, Jonides, & Shah, 2011; Klingberg, Forssberg, & Westerberg, 2002; Klingberg et al., 2005; Logie, 2012; Uttal et al., 2013).

2. Repetition versus perseveration

However, repetition is not always productive in children. School-aged children tend to loose details in repetitive productive tasks (Lange-Küttner, Küttner, & Chromekova, 2014), just like adults loose detail when they extract the gist of a narrative in their episodic memories (Bartlett, 1932). Furthermore, visual or motoric re-visiting of object locations that were inspected before leads to inefficient place memory (Danziger, Kingstone, & Snyder, 1998; Klein, 1988; Posner, Rafal, Choate, & Vaughan, 1985). This re-visiting is usually called perseveration rather than repetition (Kirkham & Diamond, 2003). Older children are becoming gradually aware of its undesirability and develop an anti-repetition bias (Witt & Vinter, 2011). However, perseveration may remain a problem of children with attentional problems such as ADHD (George, Dobler, Nicholls, & Manly, 2005; Wilding, 2003; Wilding & Burke, 2006; Wilding, Munir, & Cornish, 2001).

It has been argued that the avoidance of repeated inspection is an adaptive control bias (Wada, 1998), but not a sign of reflection (Wright & Richard, 1998). The ability to avoid a previously visited place in order to efficiently inspect all of the places of an array develops already in infancy (Clohessy, Posner, Rothbart, & Vecera, 1991). Until the end of their first year of life, human infants find it difficult to divert attention from the object shape toward its object location, and show perseverative reaching toward the place of their first object-place binding (revisiting, or better known as the A-not-B error in the developmental literature) (e.g. Lange-Küttner, 2008). Colorful valid spatial cues that make spatial fields and places more salient help infants' place memory, but experience with the spatial cues is short-lived: When an array without color cues is used, the same perseverative error happens again (Butterworth, Jarrett, & Hicks, 1982). Repeated loops of attention to previously visited places do not anymore occur when infants are 1½ years old due to a stronger drive to explore new places (Vecera, Rothbart, & Posner, 1991).

In adults, this anti-repetition bias was termed inhibition of return (IoR). It avoids attentional loops and perseveration to previously inspected places and does not show consistent age differences (Castel, Chasteen, Scialfa, & Pratt, 2003; Connelly & Hasher, 1993; Hartley & Kieley, 1995), but seems to occur due to individual differences in personality (Avila, 1995; Nelson, Early, & Haller, 1993). Adults show selective reaching biases under time constraints (Briand, Larrison, & Sereno, 2000; Howard, Lupiáñez, & Tipper, 1999), but different to infants, adults would rather return to the last visited place, and not to the initially visited place, with a gradient of weightings for IoR to previously attended places in time and space (Abrams & Pratt, 1996; Birmingham, Visser, Snyder, & Kingstone, 2007; Pratt & Abrams, 1995; Tipper, Weaver, Jerreat, & Burak, 1994; Wright & Richard, 1996). However, perseveration can occur under high cognitive load both

in children and in adults (Longstaffe, Hood, & Gilchrist, 2014; MacPherson, Klein, & Moore, 2003).

While spontaneous repetitive exploration such as perseveration makes place identification slow, inefficient and inaccurate, the *repetition of the task presentation itself* leads to a better balance in memory for the first and the second location and reduced perseveration in infants (Lange-Küttner, 1998; Marcovitch, Zelazo, & Schmuckler, 2002; Munakata, McClelland, Johnson, & Siegler, 1997; Spencer, Smith, & Thelen, 2001), in adults (Dodd & Pratt, 2007) as well as in neural networks (Munakata, 1998; Thelen, Schöner, Scheier, & Smith, 2001).

A strong effect of the repetition of the visual task itself was also found in adults' visual recognition with a computerized task (Ihssen, Linden, & Shapiro, 2010). Participants watched a display with two sets of objects, colored and monochrome shapes. It was more efficient for their recognition memory when participants saw initially one set of shapes and thereafter the second set of shapes, rather than both types of shapes in one long presentation, even though the overall time was the same in both conditions. However, repeatedly seeing both complete sets was as efficient as repeatedly seeing half the set (Ihssen et al., 2010, Exp. 1). Especially low performers improved the most after the repeated presentations.

Thus, while repetition by the participant is usually a sign of a weakness, it seems that straightforward stimulus repetition is an important learning factor where we do not yet quite understand the mechanism. It is currently suggested that *repetition* rather than *enduring presentations* work like a visual memory trace *refresher* (Camos & Barrouillet, 2011; Logie & Della Sala, 1999); a mechanism that also may be active in rehearsal (Jarrold & Tam, 2011). From studies on the value of stimulus onset and offset, it appears that the *repeated stimulus onset* is more important than the stimulus offset (Luo, Lupiáñez, Fu, & Weng, 2010; Pratt & Hirshhorn, 2003; Riggio, Bello, & Umiltà, 1998; Samuel & Weiner, 2001).

3. Repetition effects in tracking objects' locations

The term repetition priming describes that the speed of processing increases as a power function of the number of exposures to a specific stimulus (Logan, 1990), while at the same time neural activity is decreased (Grill-Spector, Henson, & Martin, 2006). Repetition priming is not only functional with words, but also when pictures and picture fragments were used (Russo, Nichelli, Gibertoni, & Cornia, 1995).

An interesting question is whether objects that were repeatedly seen in different places would be easier to memorize (Pinto, Howe, Cohen, & Horowitz, 2010). There is one visual memory task paradigm where the spatial configuration changes as part of the task: Visual memory is involved when identifying shapes and locations after they have moved around (Allen, McGeorge, Pearson, & Milne, 2006). This task was called multiple identity tracking (MIT) when the objects were visible during the movement and masked before retrieval (Pylyshyn, 2004), or multiple object tracking (MOT) when objects were masked during the movement (Pylyshyn, 2004; Pylyshyn & Storm, 1988).

In such a task, Pinto et al. (2010) required adult participants to answer the what-is-where question. For instance, they were asked 'where is the zebra?' and were awarded a location hit if there was any animal at a target (and not a distracter) location, and they scored an object hit if it was also the correct animal. In this way, the likelihood to score a hit for locations was higher than for objects. However, while the object score was lower, the gain was larger. Nevertheless, in repeated blocks both the location and the object score increased. This repetition effect occurred with colorful drawn animals as well as with geometric colored shapes.