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Effect of spatial scale on children's performance in a searching task

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ABSTRACT

The decision processes involved in searching behavior are often assumed to be similar despite differences in the dimensions of the situations in which the subjects search. However, many sensorimotor processes are modified when searching on real-life field situations, experimental rooms or computer screens. In this study we tested children in a series of setups where they searched for objects hidden beneath opaque covers. We reduced the search area from (1) a 50 × 70 m sports field, (2) a 5 × 7 m floor area, (3) a 50 × 70 cm table top, and (4) a computer game. While we found that performance was similar in the three "real-life" versions of the task, it was poorer in the computer version. In the light of these findings we discuss similarities and differences between the conditions as well as some of the implications for the use of virtual tasks in psychological assessment.

1. Introduction

How does spatial scale affect the way we interact with the environment? In daily life we solve problems on a diverse number of spatial scales – from navigating in a city to browsing the internet. Are the behavioral and cognitive processes used to solve a particular task on one spatial scale similar or comparable to those on larger or smaller-scale tasks? This question is particularly relevant to research areas using small-scale tasks as proxies for events that in real life often take place on much larger scales.

1.1. Scale and space

On a daily basis we engage in tasks involving spatial behavior across a large range of scales. Scale affects the way we perceive and understand the environment around us. If the scale of a task is small enough (relative to our size), we can probably attend to all its elements with only small movements of our eyes or head. If the elements involved are arranged in a space larger than we can perceive at a glance, we may have to extrapolate the location of some elements from experience or recent memory (Ittelson, 1970). Some entities may only make sense from afar, such as a mountain or an island, and may not be perceived from up close (e.g. we may not know that we are on a mountain if we are standing on it). In this sense, large spaces may be treated as small spaces if they are perceived from a distance (Montello, 1993). In a similar way, features on maps represent aspects of the environment we will never be able to perceive simultaneously in a daily life setting (e.g. a complete mountain range or a peninsula) and yet, which we are able to comprehend and to navigate symbolically on a map. Humans are able, even from very early ages, to manage spatial conversions, to the extent that creating and using maps is thought to be a human universal (Blaut, McCleary, & Blaut, 1970; Blaut, Stea, Spencer, & Blades, 2003; Stea, Blaut, & Stephens, 1996).

Traditionally, the field has been marked by an imperfect dichotomy based on the distinction between those aspects of a situation that can be perceived directly and those that need to be reconstructed or extrapolated from memory. Downs and Stea (2011) offer practical definitions that help distinguish two main components: Perception is "… *a process that occurs because of the presence of an object, and that results in the immediate apprehension of that object by one or more of the senses* …", while cognitive mapping is "… *a process composed of a series of psychological transformations by which an individual acquires, codes, stores, recalls and decodes information about the relative locations and attributes of phenomena in his everyday spatial environment* …". In this sense it is clear that how we interact with the environment is often strongly influenced by experience. Classifications of space include the proposal of Montello (1993) who envisioned a scheme (*figural, vista, environmental and geographical*) based on the size of the space relative to the size of the human body, and of Tversky, Bauer Morrison, Franklin, and Bryant (1999) who suggested an

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egocentric classification taking into account distortions introduced by motion. These classic works illustrate the complexity of understanding the influence of scale in our relation to the environment.

Regarding the methodologies used to explore our interactions with space and the quantification of spatial abilities, some early work criticized the use of small-scale paper and pencil tasks, arguing that they are poor predictors of spatial behavior in real-world situations (Herman & Siegel, 1978; Siegel & White, 1975). Since then, many studies have explored the relationship between real-world spatial skills and laboratory tasks (Malinowski & Gillespie, 2001; Malinowski, 2001), virtual representations of space (Lloyd, Persaud, & Powell, 2009; Richardson, Montello, & Hegarty, 1999; Waller, 2000; Witmer, Bailey, Knerr, & Parsons, 1996) and psychometric scales (Hegarty, Montello, Richardson, Ishikawa, & Lovelace, 2006; Hegarty, Richardson, Montello, Lovelace, & Subbiah, 2002). These are central aspects concerning human's relation to space, since many findings, such as sex differences in spatial behavior (Lawton, 1994; Montello, Lovelace, Golledge, & Self, 1999), or how these skills develop in children (Wellman, Somerville, & Haake, 1979), have been found using small-scale simulations of real-world environments. In addition, scaled down or virtual reality tasks that involve a reduction in motor feedback, are often used to provide training for medical (Gallagher et al., 2005; Tendick et al., 2000), military (Smith, 2010), or other personnel in risky situations, like mining (Filigenzi, Orr, & Ruff, 2000).

1.2. Searching behavior

A behavior that is fundamental to our survival and requires that we interact in an adequate manner with the environment across a huge range of spatial scales is searching behavior. Searching is part of everyday life, a common behavior which takes place at different spatial scales and scenarios but that may involve similar sets of rules. For instance, a search has been defined as the intention to locate a target under conditions of uncertainty (Todd, Hills, & Robbins, 2012). As examples we may picture the differences and similarities between the following searching scenarios occurring at different spatial scales: mushroom gatherers searching on the slopes of a volcano, shoppers trying to find a list of items in a supermarket, someone looking for a particular utensil in a jamb-packed kitchen drawer, searching for a relevant link on a web page or for a particular location on an online map. These tasks may involve different motor and cognitive components, which in turn, may be affected by spatial scale, experience and relevance. Nevertheless, such diverse situations can be analyzed and understood according to similar components comprising searching trajectories representing the movement of an agent in space, and quantified according to costs versus benefits (Stephens & Krebs, 1986).

Searchers may exploit patterns in the structure of their environment to increase the efficiency of a search, for instance, by systematically covering a search area by moving in a spiral or zigzag fashion (Bell, 1991). These searches can involve a greater cognitive demand than random searches, but may also involve a larger reward in environments where resource distribution is patterned and highly visible (Zollner & Lima, 1999). In human-generated environments, which frequently have salient geometric features, the location of items is often accompanied by certain assumptions. Everyday examples where a systematic search may prove useful are when trying to locate a book on a library shelf, or searching through the drawers of a dresser for a particular item of clothing. In such situations, certain features of the environment and past experience can provide clues as to which searching strategy to follow – where to start, places that have been visited before, how to minimize the search effort. For instance, the anchor point hypothesis (Couclelis, Golledge, Gale, & Tobler, 1987) suggests that certain aspects of the environment that have particular characteristics (visually salient, ecologically relevant) may be particularly useful in forming and 'anchoring' the elements of a cognitive map. When searching we may systematically move from anchor to anchor until the item is found. Many psychometric and neuropsychological evaluations include tests, such as the key search task (Wilson, Evans, Emslie, Alderman, & Burgess, 1998) or visual detection (Ostrosky-Solis, Ardila, Rosselli, Lopez-Arango, & Uriel-Mendoza, 1998), which can be best solved by systematic searching.

In the present study we evaluated the effects of modifying the spatial scale of a task involving salient geometric features, such as those found in many everyday settings. In a previous study (Rosetti et al., 2016) we used this task to evaluate the searching behavior of children diagnosed with attention deficit and hyperactivity disorder (ADHD) using a large-scale arena. We are now interested in the effects of scaling down this task so as to develop versions which would be more convenient for use in office or laboratory settings. However, a reduction in scale also changes various sensorimotor components and possibly motivational aspects of the task, making it potentially easier and thus less sensitive to age differences and less useful in identifying poor performers. Since searching in the large-scale arena was sensitive to developmental aspects and sex differences, in the current study we tested independent groups of children in the same range of ages and using a balanced number of boys and girls. Participants were tested on a searching task presented in three different spatial scales and two contexts in which they had to collect items hidden beneath an array of opaque covers: on a sports field, a floor space, a table top, and in a computer game providing a third-person perspective of a searching task with similar virtual dimensions to the sports field but requiring very little motor input from the participant. In the current study we used a simple experimental setup involving searching for objects hidden beneath opaque covers to explore if and how systematically modifying the scale and the search context would alter the way in which participants solved the task and how this might change during early development. Our main aim was to evaluate the effect of spatial scale on search performance. More specifically, we explored whether the scaled-down versions were equally sensitive in identifying developmental changes and possible differences in performance between the sexes as the original sports-field version.

2. Method

2.1. Participants

We tested a total of 260 participants from two elementary schools in Mexico City, with no apparent motor or developmental disabilities. Participants in three of the four experimental conditions (Floor, Table Top and Computer, see descriptions below) were recruited from one school (n = 143), while participants in a fourth condition (Field, see description below) were tested at a different school. Participants in the fourth condition were an age-matched sub-sample (n = 117) tested in the Field condition as part of a previous study of searching behavior in large-scale areas (Rosetti et al., 2016). Children from three age groups (6–7, 9–10 and 11–12 years old) were visited in their classrooms and invited to participate in the study. Using a computer program, we randomly sampled numbers without repetition and assigned them to the different experimental conditions. We then matched the randomly generated numbers in the computer with the numbers on the alphabetically ordered lists used by the schools to register attendance in order to assign each participant to one of the experimental groups described below. In the case of the second school, all selected children were tested in the same condition, Field. The