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Validation of a 3-factor structure of spatial strategies and relations to possession and usage of navigational aids

Stefan Münzer*, Benedict C.O.F. Fehringer, Tim Kühl

Psychology of Education, School of Social Sciences, University of Mannheim, Germany

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ABSTRACT

The present study examined the construct validity of a 19-item self-report measure on environmental spatial strategies. A large sample ($N > 4000$) representative for the population in Germany comprising five age groups from <30 years to 50–80 years was accessed through a survey panel. Confirmatory factor analyses supported the separability of (1) egocentric spatial strategies (including sense of direction) from (2) an allocentric mental map strategy and (3) knowledge of cardinal directions. In addition, the present study investigated the possession and use of navigation aids with a focus on computer-based assistance. Relations between self-reported spatial strategies and use of navigational aids were analyzed. However, results do not suggest a strong relation between the use of navigational aids and self-reported spatial strategies.

1. Introduction

Individual differences in learning about the spatial configuration of real environments are large (e.g., Ishikawa & Montello, 2006; Malinowski & Gillespie, 2001). Individuals are apparently aware of their environmental abilities (Kozlowsky & Bryant, 1977). However, available self-report instruments on environmental abilities differ from each other in several respects. Some instruments focus on "sense of direction" (e.g., Bryant, 1982; Hegarty, Richardson, Montello, Lovelace, & Subbiah, 2002; Kozlowsky & Bryant, 1977) while others measure preferences for spatial strategies (Lawton, 1994, 1996; Münzer & Hölscher, 2011) or types of mental representations (Pazzaglia & De Beni, 2001). Moreover, some of the available self-report measures include questions about the use of navigational aids (such as reading maps, Hegarty et al., 2002), but none of them include timely questions about the use of computer-based navigation assistance. The first goal of the present study is to clarify the concept of "sense of direction" in relation to types of mental representation of space and corresponding wayfinding strategies. The second goal of the present study is to reveal whether age groups and men versus women differ with respect to the possession and use of navigational aids and whether the use of computer-assisted navigation aids is related to self-reported environmental abilities. A large dataset is utilized for the present study ($N > 4000$) which is representative for the general population in Germany. Moreover, standardized norm data about self-reported environmental abilities for different age groups and for women versus men are provided (Münzer, Fehringer & Kühl, submitted).

1.1. Construct validity of self-report instruments

Available self-report instruments have been validated with correlational and experimental studies. These studies have considered *criterion* validity by addressing the prediction of orientation and environmental spatial learning from self-reported strategies and sense of direction (e.g., Bryant, 1982; Hegarty et al., 2002; Hund & Gill, 2014; Hund & Nazarczuk, 2009; Hund & Padgitt, 2010; Pazzaglia & De Beni, 2001; Prestopnik & Roskos-Ewoldsen, 2000; Sholl, Acacio, Makar, & Leon, 2000; Vandenberg, Kuse, & Vogler, 1985). However, the question of *construct* validity has not been studied thoroughly. Construct validity concerns the structure of separable factors involved in performances and outcomes. Ideally, a theory (e.g., a theory about separable intelligence factors and their relations to *g*) is reflected in an empirically supported factor structure (e.g., separability of visual-spatial, verbal, and numerical intelligence factors as sub-factors of *g*). Analyses of

* Corresponding author. Lehrstuhl für Bildungspsychologie, Fakultät für Sozialwissenschaften, Universität Mannheim, A 5,6, 68131 Mannheim, Germany.
E-mail address: Stefan.muenzer@uni-mannheim.de (S. Münzer).

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construct validity thus test theoretical considerations. Moreover, analyses of construct validity improve measurement, because the measured constructs are defined more precisely.

Several different aspects of wayfinding in the real world can potentially be measured through self-reports (e.g., preference for a route or a survey strategy, sense of direction, map reading ability, ability to understand directions, knowledge of cardinal directions, etc.). Available self-report instruments may be divided into two groups. First, there are instruments reflecting that individuals may differ with respect to the acquisition of types of spatial knowledge, such as route knowledge or survey knowledge, or the application of associated strategies. Second, there are self-report instruments that focus on a global and unitary concept of "sense of direction" (SOD). The present study aims at clarifying the relation between types of spatial knowledge and sense of direction. This is a question of construct validity, addressing both the theoretical relations between the concepts and the measurement of the constructs. The conceptual suggestion presented here will reflect the distinction between egocentric vs. allocentric spatial references frames. It will integrate SOD into the egocentric reference frame. The suggestion will be analyzed with confirmatory factor analysis.

1.1.1. Types of spatial knowledge and "sense of direction" in self-report measures of environmental abilities

The first group of self-report instruments reflect strategies and preferences associated with different types of spatial knowledge. Successful wayfinding may involve planning and memorization of routes, reading maps, following verbal directions, forming a mental map, etc. Seemingly, individuals differ in performing the corresponding cognitive operations (Aginsky, Harris, Rensink, & Beusmans, 1997; Devlin & Bernstein, 1995; Gillner & Mallot, 1998; Ishikawa & Montello, 2006).

Lawton (1994, 1996) developed the Wayfinding Strategy Scale that distinguishes a route strategy from an orientation strategy. People who use a route strategy focus on route information such as instructions for turns. People who use an orientation strategy utilize global reference points. Corresponding to the two separate strategies, two independent factors were confirmed with exploratory and confirmatory factor analyses, but only when a subset of the original items was included (Prestopnik & Roskos-Ewoldsen, 2000).

The Questionnaire of Spatial Representation (QSR) distinguishes between preferences for specific mental representations of environmental space, corresponding to landmark knowledge, route knowledge, and survey knowledge (following Siegel & White, 1975). In addition, items on cardinal directions and general sense of direction are included in the QSR (Pazzaglia, Cornoldi, & De Beni, 2000). An exploratory factor analysis resulted in five independent factors (Pazzaglia & De Beni, 2001; Pazzaglia et al., 2000) reflecting "general sense of direction" (Factor I), "use of compass directions" (Factor II), "preference for a survey representation" (Factor III), "landmark-centered preference" (Factor IV) and "route-centered preference" (Factor V).

The second group of self-report instruments consider "sense of direction" (SOD) as the central construct. SOD has been described as "an awareness of location or orientation" (Kozlowsky & Bryant, 1977, p. 590). Kozlowsky and Bryant (1977) measured SOD with one item ("How good is your sense of direction?"). SOD was related to pointing to unseen places in a familiar campus environment as well as to experimentally controlled spatial learning in an unfamiliar environment (Kozlowsky & Bryant, 1977). Subsequent studies extended the SOD item by up to 70 questions addressing various factors and aspects (e.g., Bryant, 1982; Vandenberg et al., 1985).

Likewise, SOD is reflected in the Santa Barbara Sense of Direction Scale (SBSOD, Hegarty et al., 2002). The scale consists of 15 items that address different aspects of real-world wayfinding, such as remembering routes, reading maps, giving and understanding directions, forming a mental map, judging distances, etc. Reliability estimates of the scale are high (Hegarty et al., 2002; Study 2). SOD is proposed to be a one-dimensional, unitary construct. In a series of studies examining criterion validity, the SBSOD measure was related to pointing performance, spatial updating (path integration), and spatial layout learning of real, previously unknown environments (Hegarty et al., 2002).

1.1.2. Sense of direction and configural knowledge in allocentric and egocentric reference frames

It will be argued in the following that sense of direction can be considered as *configural knowledge in the egocentric spatial reference frame*. This suggestion is based on two lines of reasoning. First, definitions of sense of direction (SOD) and behavioral correlates of the measure point to the consideration that SOD is the knowledge about directions to unseen targets which is related to one's own position and heading in the environment (therefore, it is egocentric). Second, a recently developed self-report measure revealed a simple factor structure that distinguishes egocentric spatial strategies from allocentric spatial strategies. The classical SOD item ("My sense of direction is very good") loaded strongly on the egocentric factor, but not on an allocentric factor (Münzer & Hölscher, 2011).

Configural knowledge means that an individual knows about the spatial relations between important places in the environment. However, configural knowledge might exist in *allocentric* form (i.e., from an external viewpoint, like a mental visual image of a map) as well as in *egocentric* form (i.e., when maintaining orientation while moving through the environment). A classic study may illustrate the difference. Thorndyke and Hayes-Roth (1982) investigated environmental learning based on either the egocentric perspective (through navigation experience) or the allocentric perspective (through map study). Personnel knowing an office building from navigation experience could solve spatial tasks that were based on the egocentric perspective (e.g., estimate directions with pointing tasks, estimate walking distances), but had difficulties with tasks requiring the allocentric perspective (e.g., locate rooms with respect to two spatial reference points, estimate air-line distances). For participants who had learned the layout of the building by studying a map, the reverse was true. In both conditions, participants demonstrated *configural* knowledge.

Sense of direction has been described as follows: "Sense of direction can formally been defined as knowledge of the location and orientation of the body with respect to the large stationary objects, or landmarks, attached to the surface of the earth. By definition, the accuracy of people's pointing responses to familiar, but non-visible, landmarks in the surrounding environment is a behavioral measure of sense of direction" (Sholl et al., 2000, p. 17). Likewise, Hegarty et al. (2002) concluded that "SOD is interpreted quite literally, in that the self-report measure is most highly correlated with measures of environmental knowledge that require one to represent one's current orientation or heading in the environment, or imagine taking an orientation in a familiar environment that differs from one' current heading" (Hegarty et al., 2002, p. 442).

Definitions and behavioral correlates of SOD thus point to the interpretation that the core meaning is the ability to orient oneself within in an environment, i.e. to relate an actual or imagined position and heading to other (unseen) places. However, with the exception of the orientation factor in the Wayfinding Strategy Scale (Lawton, 1994, 1996), available self-report instruments do not include items corresponding to the core meaning of SOD. The SBSOD scale (Hegarty et al., 2002) includes allocentric forms of