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Stress Supports Spatial Knowledge Acquisition during Wayfinding with Mobile Maps

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Abstract

We detail a novel empirical approach with in-situ psycho-physiological measurements to assess how stress influences spatial knowledge acquisition, mobile map use, and wayfinding success when performing a navigation task in an unknown urban environment. We recorded pedestrians' navigation trajectories, mobile map interactions, eye movements, and galvanic skin responses, with varying stress conditions. Our results clearly indicate that stress supports navigators in forming good survey knowledge, possibly due to enhanced engagement. This seems to emerge from their goal-oriented interaction with the mobile map. Our study results contradict earlier findings, contribute to the on-going debate whether using mobile navigation systems are harmful for humans' capacity to acquire environmental knowledge during navigation, and highlight the important influence of people's individual spatial abilities and emotional states on their knowledge acquisition.

1. Introduction

Does spatial knowledge acquisition deteriorate when people rely on mobile navigation assistance, as prior studies suggest (e.g., Gardony et al. 2013)? If yes, does it relate to disengagement from the navigated environment (Leshed et al. 2008), and/or from the wayfinding decision-making process (Bakdash et al. 2008)? These questions motivated our study. As increasing empirical evidence suggests that navigation performance can be predicted by varying individual differences, for example, spatial abilities (Hegarty et al. 2002), personality traits, such as anxiety (Thoresen et al. 2016), or emotional states, such as stress (Wilkening and Fabrikant 2011), we wondered how individual differences might interact with spatial knowledge acquisition and mobile map use.

2. Methods

Thirtyfive members (f:2; m:33) of the Swiss Armed Forces International Command (SWISSINT) participated in our study. Before the experiment participants completed a demographic questionnaire, the Santa Barbara Sense of Direction Test (in German), the perspective-taking/spatial orientation test, and the building memory test. We divided participants into two ('stress' | 'control') groups by median-split on their perspective-taking test results, such that each group contained the same number of 'high' and 'low' performing participants.

Participants were asked to navigate from a start to an end location along five waypoints in a given sequence, in an environment unfamiliar to them. They were given a mobile map application running on a tablet computer, which displayed start and end locations, the waypoints, and participants' current (GPS) position, but no prescribed routes.

Participants wore a mobile eye tracker connected to a laptop carried in a backpack, and a wrist-band[1] that recorded various psycho-physiological signals (e.g., galvanic skin responses

[1] http://bodymonitor.de/smartband/

(GSR)). The stress group participants also wore in-ear headphones. Each participant filled in the short stress state questionnaire (SSSQ) before and after the experiment to assess changes in their perceived feelings and stress-related attitude. To induce stress, the stress group was given:

1. A time limit of 14 minutes (assessed in pilot tests), indicated by a countdown timer on the mobile map;
2. A work-related search and rescue scenario (fellow soldiers missing in action);
3. A random mix of annoying sounds and disturbing noises (e.g., shooting, loud music) through the headphones;
4. On screen dialog messages and/or vibrations at irregular intervals, to be removed by pressing ‘OK’.

The control group had no time limit, but was told to reach the end point in about 15 minutes. They were asked to do a simple patrol walk while checking each waypoint in the same order as the ‘stress’ group.

After reaching the end point, participants responded to several questions to quantitatively assess their acquired spatial knowledge. Here, we only report results regarding survey knowledge, which we measured by asking participants to point back to the starting point and to each of the waypoints, and by having them estimate the distance to these points.

3. Results

Based on the SSSQ responses and the GSR measurements, the stress group appears to have been more stressed than the control group. Comparing their answers for the SSSQ before and after the navigation task, the distress score for the stress group shows a slight increase (μ=.05), while that of the control group decreased (μ= –.39). Similarly, GSRs of the stress group (μ= –188.972%) increased more than that of the control group (μ= –52.591%). However, GSR differences are not statistically significant, likely due to the large variance between participants.

The average direction estimation error shows no statistically significant difference between the two groups (‘stress’: 27.14º, ‘control’: 32.7º). However, the stress group estimated directions more consistently than the control group. In the former, errors are about the same for each point; in the latter average error for the first two estimates is over 50º, then dropping to that of the stress group for the third to fifth estimate (Figure 1).

For each participant, we calculated Fisher r-to-z transformed Pearson correlation coefficients between real-world and estimated distances for each endpoint-waypoint pair. This indicates participants’ distance estimation consistency. There is no statistical difference between transformed mean correlation coefficients for the stress group (r=.588) and the control group (r=.70). Moderate coefficients show that the distance estimation task was hard.

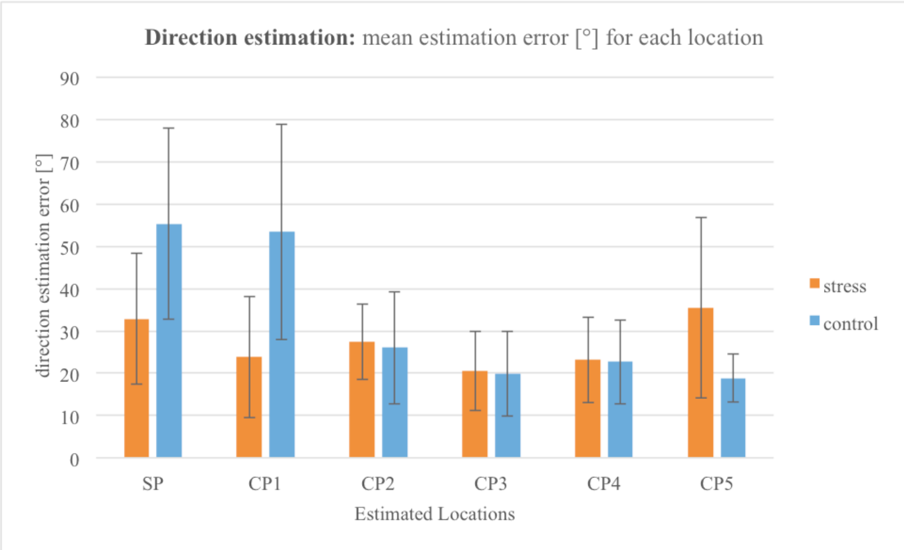

Figure 1: Mean direction estimation error of stress and control group for each location. Error bars show ±2 standard errors.

Based on their direction and distance estimations, we reconstructed participants' 'mental maps' of the environment using a bi-dimensional regression. It provides scaling and rotation factors to compare the true geographic point configuration with the pattern of the participants' estimated locations (Figure 2).

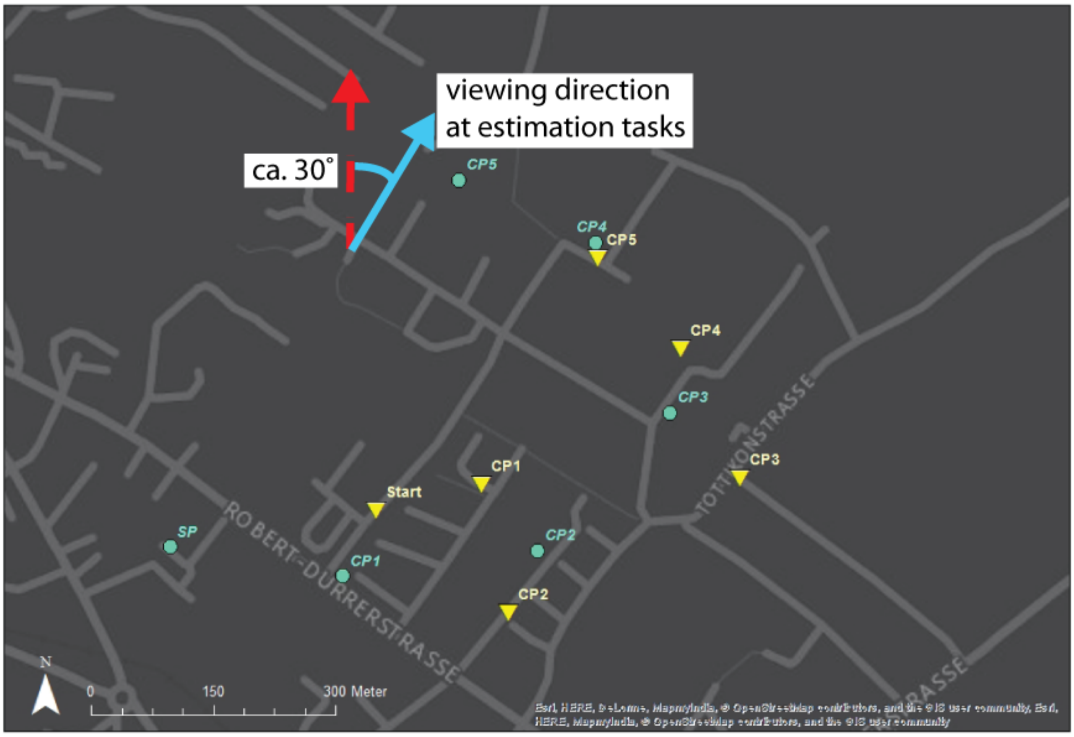

Figure 2: Geographic locations (yellow) and a participant's location estimations (blue; 'SP' corresponds to yellow 'Start'). The North arrow is in red, the participant's viewing direction during the estimation task in blue.

The variance explained by the regression model is slightly higher for the control group (R^2=.797) compared to the stress group (R^2=.764), but the predictions of the stress group are more consistent. The stress group shows less distance distortions (ϕ_x=1.183, ϕ_y=.909) in the scaling factor than the control group (ϕ_x=1.604, ϕ_y=1.331). For ϕ_y, this difference is statistically significant. The rotation factor indicates by how much the actual and estimated locations need to be rotated to align. Rotation is larger for the stress group, but again more consistent, with a clear pattern for counter-clockwise rotation (μ=-36.91, sd=6.72º) while the control group shows no clear pattern (μ=-.56º, sd=10.3º).

As expected high-spatial participants perform better than low-spatial participants in all tasks, but the difference is only statistically significant for distance estimations and for R^2.

4. Discussion

We find qualitative differences in spatial knowledge acquisition due to stress, but not as expected by prior research. Participants acquire a good level of survey knowledge despite stress, and construct a consistent mental map that we deem better than those of the control group. This is evidenced by their consistency in the direction estimation task, the regression model's scaling factors being close to 1, and the rotation angle approximately corresponding to the angle that would align the street network with the cardinal directions (Figure 2).

The stress group spent more time looking at the mobile device, as qualitative assessments of the eye-tracking data suggests. Participant gazes in the stress group seem to cover a wider area of the map compared to those of the control group, and stressed participants seem to have processed more of the information presented on the map than control group participants. While the control group seems to have exhibited the well-observed passive consumption of information presented by the mobile device, it seems that the stress group perused the map effectively for planning ahead, as to navigate the waypoints most efficiently.

To conclude, our study contributes to the on-going debate of the (potentially detrimental) effects of mobile navigation assistance on our engagement with and knowledge acquisition from the environment. Contrary to most prior work, we find that there are conditions in which environmental learning takes place, even during navigation under stress. An individual user's ability and their emotional states as so often seem to have a significant impact on solving spatial tasks, which calls for further research identifying the influence of these important factors.

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