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DISCUSSION

Navigation Aid use and Human Wayfinding: How to Engage People in Active Spatial Learning

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Abstract
In our daily life navigation systems play a pivotal role. These technical aids are used to find a way in unknown environments. Nowadays, they are already integrated into cars or available as smartphone apps. However, navigation is not necessarily successful when using such navigation aids. A highly debated but widely accepted consensus is that the increased use of navigation aids is associated with decreasing navigation skills (i.e., cognitive skills) and social interaction. In the current discussion paper, we therefore want to focus on how to reduce such (possibly) detrimental effects while engaging people in active spatial learning during the use of a navigation device. As we will demonstrate, such an active engagement can be realized rather easily and in a very simple manner: an explicit instruction (and people's will to follow it). The way the instruction and the task are presented does not seem to matter (i.e., self-read, experimenter-read, or AI-read). The most simple but decisive element for effective wayfinding may be found on the individual psychological level, rather than on the design level for artificial systems. Thus, our discussion paper wants to 1) provide ideas on how to reduce possible detrimental effects in wayfinding (short-term and long-term) and 2) stimulate research on the psychological issues in addition to the technical issues.

1 Motivation

A major part of our daily routines is spatial orientation: Workers need to find their way to work or children their way to school. Most people learn these routes by walking, riding a bicycle, or driving a car. They may also read a map or even ask a local resident. However, nowadays they rather rely on artificial intelligence (AI) in form of a navigation device or mobile app when they encounter these routes for the first time(s).

In a survey, 42% of the interviewed persons agreed on the following statement about the cognitive and social changes caused by digitalization and the use of *Artificial Intelligence*, AI [1; p.2]:

"In 2020, the brains of multitasking teens and young adults are "wired" differently from those over age 35 and overall it yields baleful results. They do not retain information; they spend most of their energy sharing short social messages, […] being distracted away from deep engagement with people and knowledge. They lack deep-thinking capabilities; they lack face-to-face social skills; they depend in unhealthy ways on the internet and mobile devices to function. In sum, the changes in behavior and cognition among the young are generally negative outcomes."

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1.1 Status Quo: Passive Use of Navigational Devices and its Consequences

1.1.1 Overreliance, Overuse, and their Consequences

As a starting point, we need to put the above quote into the appropriate research context, which includes a brief overview of detrimental effects of AI (over)use in human spatial navigation and our cognitive abilities. [1]

Our navigational skills developed throughout evolution. Today, we can train them by seeking navigational challenges in daily live [2, 3]. He and Hegarty showed in their study that different factors (e.g., the growth mindset and spatial anxiety) influence the acquisition of spatial knowledge. People believing that their ability–here the ability to navigate–can be improved (i.e., growth mindset), look for navigational challenges more often than people not believing to achieve their goals (i.e., fixed mindset). The authors theorized that people possessing high-level spatial anxiety

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tend to *ask* the navigation aid (an AI system) for advice and then fully rely upon it.

In this discussion paper we address navigational aids in a relatively broad but *technological* context: Navigational aids are, for example, GPS-based navigation systems which are built into cars, and Apps which are already pre-installed on most smartphones (e.g., Google Maps). As a result of overreliance on and overuse of navigation aids, people with high-level spatial anxiety do not show improved navigation performance due to a lack of inner navigation skill practice.

The long-term consequence is that our abilities to navigate slowly decrease or even decay. In other words, we should use our navigation skills or we are about to lose them [4]. Navigational aids are changing our spatial cognitive abilities by manipulating the amount of offered opportunities to *spatially learn* and the spatial learning process itself. Then, the decay of the navigation abilities is one of the inevitable outcomes that Anderson and Rainie [1] implied.

On the one hand, this decline of skills can be related to anxiety and mindset, while, on the other hand, mindset and anxiety are related to spatial skills. We call this the reciprocal approach to describe the circular relationship between the overreliance and overuse of navigation aids with the accompanying detrimental effects on spatial cognition. It is possible that these detrimental effects can also indicate changes in the structure of the brain itself. On the positive side, Maguire et al. [5, 6] showed an increased hippocampus volume due to the permanent engagement in route planning and navigation. On the negative end, a slight hippocampal atrophy has been demonstrated by Stahn and Kühn [7] in astronauts. Due to long space missions and, therefore, due to the *extreme spatial condition* (i.e., zero g), spatial cognition and its neural basis could be changed by the environment itself. The environmental factor cannot be changed by human beings individually. But humans can shape their neuronal system by learning and/or challenging their navigation skills and strive for active interaction with navigation aids.

1.1.2 Objectives of the Present Work

We want to emphasize that the use itself can differ between people and therefore can have a different impact on spatial cognition. We want to show that the detrimental effects, the "cognitive erosion" [e.g., 4], is (mainly) linked to a disadvantageous interaction, namely *passive navigation* (e.g., "No matter where I am or where I want to go, I always use my navigation system."). Thus, it is not a problem of the navigation aids. It is the interaction and the *type of use* that must be taken int account.

One underlying mechanism of the inefficient use is that people no longer *actively* navigate or must find the right way to a destination in unknown terrain. This is realized by the navigation systems. The consequences of using such systems in this way are well-known: These aids free the user from the necessity of engaging with the environment to find the right way [8]. People no longer need to actively participate in planning a route, they do not need to encode or transform spatial information [9], they only need to follow the information given by the navigation-system. This leads to a change from *active* to *passive* navigation. The systems adopt and imitate the strategic and therefore cognitive task of navigating by providing spatial information and facilitating the navigation process [10]. These spatial AI systems solve problems, mimic mannerisms, perform human tasks [e.g., 11, 12] and, therefore, work in a cognitively adequate (i.e., comparable) fashion. All the above is linked to poorer spatial skills, for example, decreased (landmark-based) wayfinding performance [e.g., 13, 14, 15] and sometimes with severe consequences [16].

1.1.3 "Human Error"

Some consequences may not only result from the fact that these systems cannot always and instantly provide correct directions in a rapidly changing environment, which about 82% of American citizens have experienced [17]. These incorrect route directions aren't similar at all, they differ in their impacts depending on the passive use of navigation aids and other factors: Brooks and Rakotonirainy [18] investigated the causes of car accidents and stated that more than 20% are caused by distraction, for example, by the navigation aid. As stated above, this passive use of navigation aids results in a *naïve* route following behavior. For instance, an American woman got injured because of *walking* on a busy highway instead of stopping at a barrier for pedestrians. In 2021, a delivery driver got stuck on a narrow sidewalk next to train tracks with his car because of simply following the instructions of his navigation aid [19, 20]. Even US Rangers got a special term for people dying as a consequence of *blindly* following the navigation aid and, therefore, passive navigation: "Death By GPS". This phenomenon may therefore not just be called an *individual case*, it rather represents an increasing problem [21, 22]. Those risks and accidents are not provoked by the device itself but occur while interacting with it. In most cases these devices work in the way they were intended to do. These risks and accidents have to be attributed to the user and their adverse interaction. This is called the "human error" [e.g., 23]. In line with this notion is the result of a survey that we conducted in three different countries. It revealed that quite a few German (approx. 34%), British (approx. 26%) and American (approx. 47%) participants tended to blame the navigation aid for getting lost (i.e., external attribution; please note that it is the navigator herself who has to make the final route decisions at present; this may change in autonomous driving).

However, still very many people correctly attributed the mistake to themselves. In the second part of our discussion paper (Quo Vaids: From preliminary results to future research and development), we will describe reasons for this human error and how to change the use of navigation aids – which we identified as the key feature leading to this *passive* navigation.

A possible reason for such inappropriate behavior and the human error is inattention. To effectively navigate and learn a new route or any other spatial content, people need to be attentive. This attention is divided when using navigation aids. Users need to pay attention to the road they drive or walk on and to the navigation system itself and its characteristic–partly multimodal–features (e.g., visual information for indicating the updated position with an arrow and auditory information as the voice instructing to make a turn). This divided attention leads to impaired wayfinding [24]. Divided attention conflicts global processing of spatial information [14] and navigation system use can also lead to inattentional blindness [25].

Another reason for the human error is the cognitive *disengagement* with the environment and the negative influence of navigation systems on developing cognitive maps [26]. Yet, two epistemic approaches play a crucial role in this context: virtue reliabilism and virtue responsibilism [16]. The first describes cognitive abilities (e.g., memory and reasoning) which establish reliable beliefs of the environment. The latter includes intellectual autonomy, attention, and carefulness. The navigation device already provides the *beliefs* so that there is neither the need for people to establish an internal map, nor to engage with the environment to check one's own position with an external map. These tasks are inherent properties of the navigation system; people only need to follow the route directions given by the device [27], which is then simply a motoric response. The reliance on and the trust in AI-based systems in this context seems to be (at least partially) rooted in the individual belief of a disability to navigate. Although most Americans experienced incorrect route decisions [17], our own (unpublished) survey revealed that German, British and US American participants assumed computer-based navigation aids are reliable most of the times. If asked to find a way in an unfamiliar environment people tend to *ask* computer-based navigation systems instead of a real person. In Germany approx. 70% of the participants, in the UK approx. 71% and in the USA 81% prefer a computer-based navigation system over information provided by local residents. The overall trust in (here AI driven) navigation aids is high, and people prefer interacting with them. This indicates that we should keep the key role of the interaction for further research in mind and should concentrate on the following questions: Why is the interaction so important and why does it lead to a passive use? How can it be changed so that it does not lead to the presented spatial skill loss?

One possible reason for the passive use could be spatial anxiety. As a side note to the relationship between trust and spatial anxiety, many participants come to our lab saying: "I want to learn more about spatial navigation, since I am really bad at that". Such personal experiences (i.e., internal attribution) may contribute to spatial anxiety, while spatial anxiety can result in higher dependence on navigation systems [2]. It is possible that there is a reciprocal/circular relationship between reliance on navigation aids and lack of practice as described above. In the end, this may lead to a decrement in navigational skills.

1.2 Individual Factors: Strategies and Abilities Contributing to Passive Use and Detrimental Effects

Furthermore, learning abilities and strategies as well as social interaction must be considered, since every factor is influenced by navigation systems' use and may therefore influence spatial orientation. Nuhn and Timpf [28] suggested a more personal model of factors having an impact on navigation (i.e., identifying an object as a landmark). Individual knowledge, background, interests, and traits play an important role (here for landmark selection). These findings are not identical but equivalent to He and Hegarty [2] and describe important aspects also in terms of using navigation systems as an aid. These more personal factors can be used to manipulate the way someone uses a navigation system by–as we did on our experiment focusing on wayfinding and instruction–integrating explicit instructions in multiple ways.

As we already showed, the most important aspect, including the factors mentioned above, that can result in less effective learning is the interaction between environment, the user, and the interaction with the navigation system [29]. Willis [29] claimed that errors in wayfinding occur in translating between these factors. Knowing that the translation and, therefore, use is a crucial factor, it is possible that it can be manipulated–for example by an explicit learning instruction or even implementing landmarks.

Siegel and White [30] stated that by simply walking through an environment, children develop a cognitive map and therefore learn to navigate. Simply using a navigational aid does not result in the development of a proper cognitive map–for example, because of divided attention and as mentioned above inattentional blindness [31].

Using a navigation aid that presents route information as turn-by-turn guidance does not necessarily lead to poorer navigation performance. Kelly et al. [32] showed a contrary result to the negative effects we discussed so far. In their study, all participants learned a route by guidance (turn-by-turn) first, then the participants were assigned to the different groups which both took the route a second time. One group had to recall this route and received corrective feedback whereas the other group was guided along the route again (by turn-by-turn guidance) a second time. In a final test they showed that only turn-by-turn guidance in comparison to retracing the route does not affect route knowledge. This indicates that turn-by-turn guidance does not necessarily lead to decreased spatial cognition performance.

Assuming that it is possible to learn spatial information by guidance as good as by active navigation being given an instruction can lead to better results in spatial tasks (for example, co-drivers are more successful in remembering a route if given an instruction to learn the path). Explicit instructions to memorize specific spatial information can prime the participants [e.g., 33]. This priming seems to be a crucial factor for a beneficial use of navigational aids. If the instructions explicitly state to remember a route it seems possible that people learn from the navigation system, since they engage with the spatial task.

1.3 Quo Vadis: From Preliminary Results to Future Research and Development

1.3.1 Recent Research and Preliminary Results

We here want to introduce some preliminary results from wayfinding and the accompanying learning process (based on different instructions). There are different stages of wayfinding: Know the location someone's in, plan the route and know the destination (planning and using knowledge stored in memory), and execute the route. The use of navigation systems impacts the second stage by outsourcing the task of planning and knowing the destination [25]. The mechanism underlying navigation system use is called *guided navigation*, because users only must execute the action [32]. The navigation system functions as intended by reducing the amount of information that must be processed. In line with this assumption is Münzer et al.'s [6] finding that AI guided navigation resulted in worse route memory than map-based navigation independent from how the AI guidance was designed.

Our idea is to follow these studies investigating the cognitive and social mechanisms of AI-guided navigation. We want to refer to route knowledge as information about turns on a given route and can, for example, be measured with route repetition tasks [33]. We address the passive use of navigation aids which is linked to the negative effects stated above. We assume that with an *explicit instruction* the guided (i.e., *motoric*) navigation, simply following the route directions, could be changed to an *active* navigation–to an active learning process and memorizing the directions. This might help to compensate for the negative effects demonstrated above. The instruction may affect spatial learning as preliminary results show.

Knowing that an instruction affects spatial learning, it is possible that the level/degree of social interaction (for example by whom the instruction is given) is also to be considered, since social interaction is very likely to be influenced by AI, too.

In a current online study, focusing on wayfinding and a general learning instruction, participants [$N = 136$] had to learn a route with route directions implemented in screenshots of intersections adapted from the studies by Hamburger and Röser and Hamburger and Knauff [34, 35]. Participants had to only watch a video of the route (*visual exposure*), whereas others were instructed to navigate through the presented route by simply following the directional information via key presses indicating the passive use of navigation aids (*motoric task*). To examine the participants' engagement in the navigation process in both presentations of route information a relatively simple learning instruction was provided. If an explicit learning instruction was given, we labeled them *(cognitive) active*, if there was none, we called it *(cognitive) passive*. Descriptive results revealed that wayfinding performance increased if a (learning) instruction was given (in contrast to the *motoric task* or *visual exposure*), indicating that this simple design feature can easily change passive use to an active one. Following these results that an instruction and therefore interaction leads to active wayfinding, we then varied the presentation of the instruction (*instruction self-read; instruction experimenter-read; instruction AI-read)* to examine these positive effects further (see Fig. 1). In this experiment focusing on the instructions' variation, a one-factorial analysis of variance between these conditions revealed a significant result [$F(4) = 5.25$, $p < 0.001$]. For further analysis, t-tests were conducted revealing three significant effects (see Fig. 1).

1.3.2 Interpretation of Current Empirical Results

What do we learn from these results? First, our findings support the "human error", since most people blame themselves for getting lost (i.e., internal attribution). However, they trust in the navigation aid itself and its (hopefully) reliable information so that it seems necessary to address the interaction with the navigation aid and its design (by focusing on the engagement and therefore implementing an instruction).

The system itself does not seem to be the source of the detrimental effects researchers described thus far (see Status Quo section) but rather the way people use these technical navigation aids. Ishikawa and colleagues showed that test persons navigating by a device got lost more often than persons who had to navigate by themselves, for example, by using a map. It seems that for the passive route (simulated by the *motoric tasks*) learning and recall is usually

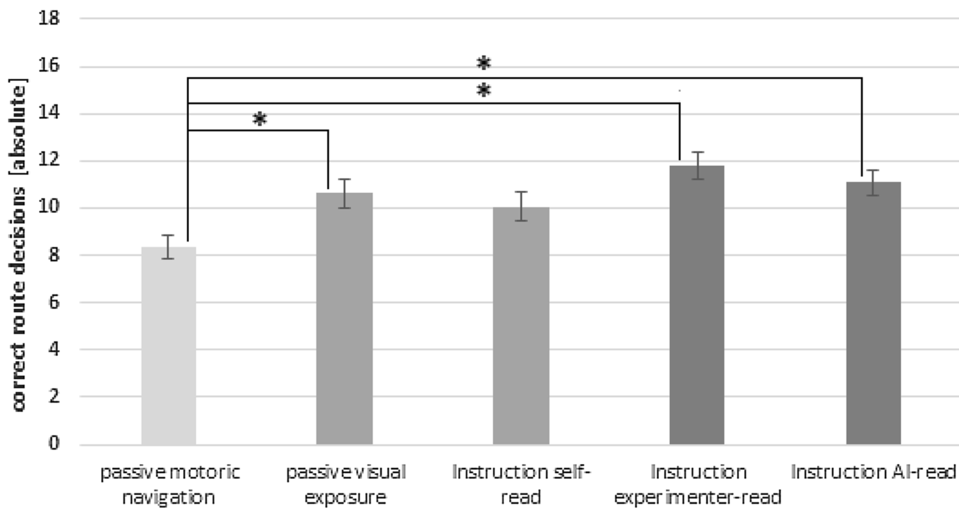

Fig. 1 Comparison of the mean absolute correct route decisions in the wayfinding task across the five conditions; error bars denote the standard the error of the mean; * indicates significance; $p < .05$

accompanied by a decreased ability to navigate or at least by a poorer wayfinding performance in such experiments [14]. The active planning (i.e., cognitive component of navigation) is usually done by the navigational system but we showed that this adoption of cognitive tasks is not the cause of the described negative effects. It is the false use, passively following a route (i.e., from a cognitive rather than motoric perspective) and not engaging in the navigation task itself that we identified as the important underlying process. For example we revealed a significant difference between the *passive motoric navigation* and the conditions in which engaging in the navigation task was established by implementing an instruction read by the experimenter [$t(110) = 4.433$, $p < .001$] or an AI generated voice [$t(110) = 3.742$, $p < .001$] .

1.3.3 Where to Go From Here?

We demonstrated an increase in wayfinding performance depending on whether there (simply) is an explicit learning instruction or not (i.e., attention is shifted from passive to active engagement). Furthermore, it seems possible that in addition to the explicit instruction, motivating an active learning process itself provokes interest (and intrinsic motivation) and, therefore, results in even more effective spatial skills (or strategies).

This shift from passive to active not necessarily depends on how the information is presented. Also, aside the design principles Ruginski et al. [36] presented–which focused on the spatial information presentation itself–another relatively simple design principle should be considered: We propose with our preliminary findings to also focus on the instruction for minimizing the negative effects navigation systems and AI in general may have when using them in an inappropriate fashion.

Future works should consider not just focusing on the *when* and *why* people use navigation systems but on the *how* and *how could the use be cognitively beneficial*. Not only the personal dimensions Nuhn and Timpf [28] introduced and the reciprocal approach by He and Hegarty [2] could be starting points which research should consider and already has considered [e.g., 36]; but implementing proper instructions to enhance wayfinding through individual engagement when using a navigation aid may be a first valuable step forward.

Remarkably, we identified that not only the explicit instruction itself plays an important role but the way it is presented. Simulating a *dialogue* or a kind of social interaction could be of importance as well. Focusing on interaction, participants are explicitly made aware of learning by an instruction. In doing so, the way how attention is shifted to an active learning process, it seems of minor importance by whom (a person or an AI-generated voice) the instruction is given.

As already mentioned, social interaction seems to be important for navigation. However, we assumed that participants taking part in the self-read condition would score higher because of the active part of reading by themselves (i.e., deeper level of processing) instead of only listening to it which is not the case (Fig. 1).

In general people who are led along a route by another person performed better on average in wayfinding than persons led by a digital navigation system [14], although it can as well be labeled as a guided navigation task [31] and therefore passive. A reason for the different results could be the personal contact with another person since this contact leads to emotions and, therefore, deeper processing [37]. Accordingly, AI and navigation systems influence social interaction. An example for this relation is given by Aporta and Higgs [38]: Inuits living under harsh circumstances for navigation pass knowledge on how to navigate on to the next generation–so navigation is an issue of social interaction. By using a navigation system, younger generations do not learn how to navigate anymore (cognitive component), they entirely rely on the device so that they cannot teach younger generations this spatial knowledge (social component) any longer. This example nicely demonstrates how navigation systems are connected to the navigation process itself and social interaction, and how AI influences both [e.g., 38].

We identified in the presented preliminary results a tendency that this is the case: The instruction itself is helpful but the most helpful if it's given by a voice. That listening to an instruction leads to better wayfinding is in line with Pea et al.'s [37] findings but we took it one step further: Even the simulation of social interaction leads to emotions and deeper processing. This deeper processing leads in a second step to better wayfinding performance. The surprisingly non-significant *t*-Test [$t(110) = 0.901$; $p = 0.370$] shows that the AI-read instruction had almost the same positive impact on wayfinding than the experimenter-read one.

One possible explanation for this finding could be that AI simulates human behavior with respect to the navigation task: Instead of asking another person or to listen to verbal directions provided by other humans, we nowadays rather tend to consider navigation devices in the spatial domain. It is not only, as Willis [29] indicates, the interaction between environment, technology, and the individual itself, it could be described as a sort of *social interaction* but with an artificial intelligence or the navigation aid. Our initial survey could be helpful here: It was asked if persons found themselves lost whether they would prefer to ask a stranger (local resident) or a navigation system for help. Most participants answered that they'd rather *ask* a navigation system. In other words: They trust in navigation systems and moreover they rely on them. In line with this finding is that most participants in this survey stated that they use navigation systems frequently or very frequently and that the information given by their device is most of the time very reliable. One feature we try to abstract here is the frequency of navigation system use and how familiar *an average person* is with navigation aid features, especially the AI-generated voice. Instead of being suspicious, the voice is associated with reliable navigation information. Therefore, it seems plausible that participants made no difference by whom the instruction was given as long as they can understand the voice and perceive it as reliable.

1.3.4 From Spatial Cognition to a Broader Context

Taking Kelly et al.'s [32] findings that the guided navigation itself does not lead to poorer route retracing, we put the widely accepted mechanism of 'use it or lose it' in a broader context. One could now ask whether the use of AI not only affects spatial abilities but also cognitive abilities/performance in general and/or social interaction? A computer is a digital device created to support us (it somehow simulates cognitive processes), reducing cognitive load for the user but also cognitive performance in case of overreliance and overuse: For example, having a computer at home can decrease performance at school [39] and using a computer in school can decrease performance in several participants [40]. A prominent example for AI influencing cognition is Google. Especially using Google points to shallow information processing [41] and thus decreased cognition. If test persons are convinced that information can now or later be retrieved from the internet, their performance in mentally recollecting this information will be worse. In addition, recognition of this information is far worse than remembering the place where it is stored on a computer [42]. But all these negative effects could be reduced by transforming the passive interaction with an artificial system to an active learning process. We found that an explicit instruction inflicts this change. We assume that this instruction can increase wayfinding performance and therefore can be a helpful tool to stop the so-called erosion of the cognitive ability to navigate when using navigation systems. We do not present the only or the one way how to stop the cognitive erosion. But it is a simple, very easy-to-realize, and promising way for navigation aid use that we should investigate further (i.e., it is very economic). Taking Pea et al.'s [37] findings into account and having in mind that 95% of German teenagers (13–15 years old) owning a Smartphone [43], it is important to motivate the *appropriate* use (i.e., what seems to be the correct use from a cognitive point of view). On the one hand, this will very likely diminish the detrimental effects and also offer opportunities for healthy cognitive aging. On the other hand, it may motivate young children to engage in spatial learning and maybe learn from AI systems in general. Engaging in spatial learning could result in less spatial anxiety and more spatial challenges. As a result, this could turn around the circular relationship mentioned above.

An important feature of an active use is simulating a social interaction by implementing recorded voices. In doing so, it seems irrelevant whether it's an actual human voice (i.e., *experimenter read*) or an AI generated voice (i.e., *AI-read*). Having in mind that most AI driven navigation aids already are equipped with a voice for verbally providing the route directions (for example: "Turn left"), it would need minimum effort to implement an explicit learning instruction but with maximum effectiveness (in case that people are willing to engage with the device, which is a topic in its own rights and may also require appropriate incentives, for which we cannot provide a simple solution here at this point). Implementing an instruction may lead to an active use of navigation aids and engagement with the navigation process itself. We showed that the negative effects of using navigation systems can easily be tackled and–ironically–even by a navigation-system feature itself–an AI-driven voice. Further research should not only concentrate on how navigation system use negatively affects human-beings but on how they can be used so that they are beneficial.

2 Conclusion

We were confronted with the Corona Pandemic and more than ever with climate change issues in which the important role and positive effects of AI can be demonstrated. Therefore, it is important for many domains–we here focused on spatial cognition–to provide the users with AI systems that are able to engage the users so that they are actively participating in the task. It seems ironic but it is possible that the cause per definitionem of the so-called "Death by GPS" can also be the *preventing entity* of these unnecessary casualties. As Willis [29] put it and as He and Hegarty [2] suggested: It is not the navigation system itself but the individual and therefore a character-dependent interaction that has to be considered once more. We clearly demonstrated on the rather simple level of spatial cognition that the *in/correct* use of navigation systems influences our spatial cognitive abilities. We presented not only a psychological proposal that may lead to a better use of a navigation aids but a starting point for further and *more optimistic* research: It is the *cognitively more effective* use of, the dealing and interaction *with*–not the device itself and its features like the presentation of information–that has to be considered further. Therefore, it is possible that this effect of a more effective use can be found or triggered in other domains as well (i.e., Corona pandemic, climate change). Our vision is that we presented here not only a (rather simple) way to overcome the cognitive erosion but also a way of navigation aid use that should be actively learned from an early age. To reach this goal, we also need to create a certain form of awareness of the accompanying benefits of correct use: for example, healthy cognitive aging and prevention/slowing of degenerative processes due to cognitive engagement throughout the lifespan.

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