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ORIGINAL ARTICLE

A proposal and preference evaluation of route line design for Augmented Reality (AR)

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Abstract:

Augmented Reality (AR) seamlessly integrates the real environment with virtual objects, enriching users' information perception. The application of AR in personal and vehicular navigation tasks facilitates the evolution of navigation systems from two-dimensional (2D) to three-dimensional (3D) representations, incorporating an egocentric viewpoint. Spatial knowledge, specific navigation objectives, navigational skills, and the navigational symbols plays pivotal roles in map utilization, encompassing self-localization, proximity, navigation, and event awareness. The representation of symbols in navigation tasks relies on static and dynamic or animated visual cartographic variables. In this context, our research focuses on evaluating symbols used for depicting routes and landmarks in AR systems during personal navigation tasks. The experiments investigated the representation of routes, exploring variations in route line thickness, the presence or absence of border-color, fill color, and the speed of arrows moving along the route line. The findings of the study reveal that thinner route lines significantly contribute to enhance perception of surroundings, blue fill color exhibit superior performance compared to traditional navigation system colors, and volunteers noted that the arrow animation speed noticeably affected their perceptions of elements within the scenario. These insights contribute to understanding of how visual variables influence user preferences and experiences in AR-based navigation tasks.

Keywords: Augmented Reality (AR); Routes; Visual Variables; Personal Navigation.

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1. Introduction

Augmented Reality (AR) is defined as the amalgamation of the real environment with virtual objects to enhance and supplement the information perceived by users, fostering a sense of immersion and enabling natural interaction with both the real environment and virtual elements (Azuma et al., 2001; Bobrich; Otto, 2002; Kan; Kaufmann, 2012). As delineated by Azuma et al. (2001), three fundamental characteristics distinguish computational systems equipped with AR: the fusion of virtual elements and the real environment; interactivity and real-time processing; and conceptualization in three dimensions. Notably, a fourth dimension, time, can be recognized as an additional fundamental characteristic of such systems.

In recent years, AR has garnered attention for its diverse functionalities and applications. Notably, AR has found utility in supporting both personal and vehicular navigation, prompting a shift in navigation platform systems from two-dimensional (2D) to three-dimensional (3D) representations. Instances of AR employed in navigation tasks include the integration of augmented reality features in smartphone applications designed for personal navigation, such as Google Maps (2023), Maps AR (2023), and AR GPS Drive/Walk Navigation (2023). This evolution in navigation technology has led to the emergence of the Visual Position System (VPS), a prominent form of AR-based navigation technology leveraging the capabilities of the human visual system (Bolter et al., 2013; He et al., 2020). One notable advantage attributed to this form of representation is its potential to alleviate cognitive load compared to traditional 2D maps, owing to its closer resemblance to the visual perception of the real world (Dong et al., 2021).

Darken et al. (2001) assert that navigation as the cognitive process through which individuals ascertain both their relative spatial position and the positioning of other elements within the landscape. Subsequently, this acquired spatial awareness is utilized to strategize and execute movements towards destinations. This multifaceted process of navigation can be categorized into distinct user tasks, elucidated through cartography: self-localization ("Where am I?"), proximity ("Where am I going to?"), navigation ("How can I get there?"), and event ("And now?") (Borenstein et al., 1996; Hunolstein; Zipf, 2003). However, significant variations exist in individuals' navigation behaviors, potentially stemming from differences in spatial knowledge levels, diverse navigational objectives, and variations in navigational proficiency (Golledge et al., 2000; Tverksy, 2018). Delving into spatial knowledge, the geometric structure of environmental cognition encompasses discrete elements such as points (e.g., landmarks, notable stationary features), lines (e.g., roads, routes, and networks), nodes (e.g., intersections), areas (e.g., regions and neighborhoods), and volumes or surfaces (e.g., physical surfaces) (Lynch, 1960; Golledge, 1999).

In the realm of navigation and vehicular tasks, applicable to both indoor and outdoor settings, the utilization of cartographic systems is indispensable for route definition and guidance (Dong et al., 2012; Nikander et al., 2013; Epstein et al., 2017). In this pursuit, Cartography leverages visual variables to design cartographic symbols supporting navigation tasks. Notable examples include lines denoting routes in navigation systems and Points Of Interest (POI). In the domain of personal navigation, the simultaneous demands on attention and potential interferences from the real environmental context, encompassing elements such as noise, people, and other vehicles, pose challenges when assimilating information from maps. With technological advancements and their consequential applications in digital cartography, digital map interfaces exhibit significant potential for the presentation, updating, and representation of dynamic content. These interfaces are readily adaptable to individual user preferences (Paelke; Sester, 2010). In the design of maps, in particular dynamic ones, the limiting factor is no longer the hardware, software, or data, but rather the constrained visual and cognitive processing capacity of the map-reader (Harrower, 2007). In the specific context of personal navigation, a paramount challenge resides in maintaining the user's attention and orientation during movement.

Drawing upon the foundational insights provided by scholars such as Bertin (1983), Dent et al. (2009), and Slocum et al. (2009) regarding the design of static cartographic symbols, a set of static visual variables were initially outlined by Bertin (1960/1983) as position, size, shape, value, color hue, orientation and texture. In digital environments, the representation of symbols extends beyond static visual variables to encompass dynamic variables (Dibiase et al., 1992;

MacEachren; Blok, 1999; Kraak, 1999). DiBiase et al. (1992) identified three dynamic visualization variables (duration, rate of change and order) and MacEachren (1995) added three more (display date, frequency, and synchronization). Peterson (1995) distinguished the animated variables as size; shape; position; speed; point of view; distance; scene; and texture, pattern, shading, and colour. This framework provides understanding of the elements essential for the effective design and representation of cartographic symbols in both static and dynamic digital contexts.

While certain constraints, such as screen size limitations necessitating adaptation, are acknowledged (Baus et al., 2005), transitioning from an allocentric to an egocentric view markedly enhances visualization quality and fosters user trust in the representation (Dong et al., 2021). From the user's point of view, situated in the central field of the map, the cartographic representation's coverage area is inherently more confined compared to the 2D maps. Despite this limitation, there exists the possibility of overlaying pertinent information to augment navigational support. In this context, the user's egocentric view governs their orientation, aligning with propositions by Burnett (1998) and Crundall et al. (2011), while the design of 3D symbols in perspective relies on existing literature. Regarding map symbols, certain objects within a car driver's visual field, such as traffic lights, crosswalks, or bridges, may serve a more suitable POI to supporting navigation tasks for drivers (Burnett, 1998; Burnett; Lee, 2005; Crundall et al., 2011). Conversely, a pedestrian's focus tends to be directed towards different urban features, influenced by their low speed of movement and distinct spatial realm. Consequently, buildings may be deemed more fitting landmarks in the pedestrian navigational context (Ross et al., 2004).

Animations find common utility in scientific discourse, with their efficacy evaluated through usability assessments yielding distinct outcomes (Castro-Alonso et al., 2019). Examination reveals that animations exert a moderately positive impact on learning outcomes, particularly when conveying procedural knowledge, representational animations, and high-fidelity animations, as compared to static images (Berney; Bétrancourt, 2016; Wagner; Schnotz, 2017; Ploetzner et al., 2020). However, varying conclusions emerge from studies suggesting that the inclusion of extra information in animations may diminish their efficiency and effectiveness. In the realm of Cartography, numerous researchers have delved into designing recommendations for dynamic symbols (Harrower, 2007; Woods, 1995; Mayer, 2002; Mayer; Moreno, 2003; Duckaczewski, 2014). Several criteria aimed at facilitating the control and direction of attention in dynamic representations have been identified, encompassing factors such as accessibility (e.g., ensuring the user can comprehend the information), information content (ensuring the sign provides sufficient information to direct attention to the marked area), and mental economy (ensuring the representation is processed with minimal cognitive effort) (Woods, 1995; Mayer; Moreno, 2003). Implementing these solutions visibly enhances the efficiency of content presentation. By concentrating the user's attention, it becomes feasible to reduce the effort required to locate information essential for a comprehensive understanding of cartographic communication.

The visualization of cartographic content in AR necessitates meticulous consideration due to its demand for dynamic real-time representation and synchronization with human visual processing (Çöltekin et al., 2020; Wang et al., 2022). Numerous scientific inquiries have been undertaken to assess the appropriateness of cartographic designs tailored for AR, particularly focusing on personal and vehicular navigation maps. However, a noticeable gap exists in the literature concerning the application and evaluation of dynamic and animated symbols in AR derived from the dynamic and animated visual variables inherent in Cartography. In this research, the hypothesis is that static or dynamic visual variables will distinctly influence visualization accessibility, consequently affecting the cognitive load during navigation, even under diverse figure-ground separation contexts. Therefore, the route line representations that best contribute to figure-ground separation and cause the least cognitive effort for reading and understanding will be more accepted by users.

The primary aim of this research is to assess the application potential and identify the most pertinent aspects of specific static visual variables (thickness and color hue) and animated variable (speed) within the domain of Cartography, specifically in the representation of routes for personal navigation tasks using AR. This investigation involved the evaluation of visual perception among 20 volunteer participants while performing four designated tasks. The selected variables were thickness of the route line, route border-color, route fill-color, and the movement speed of directional arrow symbols along the route line. Collected data encompassed quantitative and qualitative analyses of the participants' performance, including the number of glances for choosing the representation, time of choice, and participant comments.

2. Cartographic design for route line in Augmented Reality (AR)

The cartographic symbol design for this research aimed to evaluate four distinct representations of a route, varying in: line thickness, border color, fill color, and arrow movement speed along the route line. To facilitate the visualization of the 16 line projects conducted in the research, Figure 1 presents the four possible route line designs for each task. This way, participants could view each line design in its entirety. The experimental setting for designing these routes encompassed an external area of one of the teaching blocks within the Federal University of Paraná (UFPR), campus Centro Politécnico in Curitiba, Paraná, Brazil, during November 2022. The experiments were conducted in a controlled environment, free from noise, with adequate luminosity, within a closed room. To simulate people's egocentric perspectives while traversing the university blocks, four scenarios with sidewalks were selected and recorded using a smartphone camera (Figure1).

The thickness of the route lines was designed proportionally to the sidewalk, offering four variations: 9%, 12%, 16%, and 19%, respectively (Figure 1a – strips A, B, C, and D). Consequently, it is discernible in the image that both the sidewalk width and route thickness decrease by two-thirds as they move away from the lower central point of the screen, the point of origin and orientation for the viewer, attributable to the camera perspective effect. The route border-color design incorporated four color options: no border-color or the same filling color (RGB: 68; 114; 196); light gray (RGB: 167; 167; 167); dark gray (RGB: 167; 167; 167); and dark blue (RGB 47; 86; 154) (Figure 1b - strips A, B, C, and D). Options for the color fill of the route line encompassed green (RGB: 84; 30; 53); orange (RGB: 197; 90; 17); blue (RGB: 68; 114; 196); and red (RGB: 192; 0; 0) (Figure 1c - strips A, B, C, and D). The design for arrow movement speed over the route line offered five gradual choices: 0.25 cm/s (slow); 0.30 cm/s; 0.35 cm/s; and 0.40 cm/s (fast) (Figure 1d - strips A, B, C, and D). For the variables of line thickness, route border-color and arrow movement speed, the route fill color was standardized as blue (RBG: 68; 114; 196).

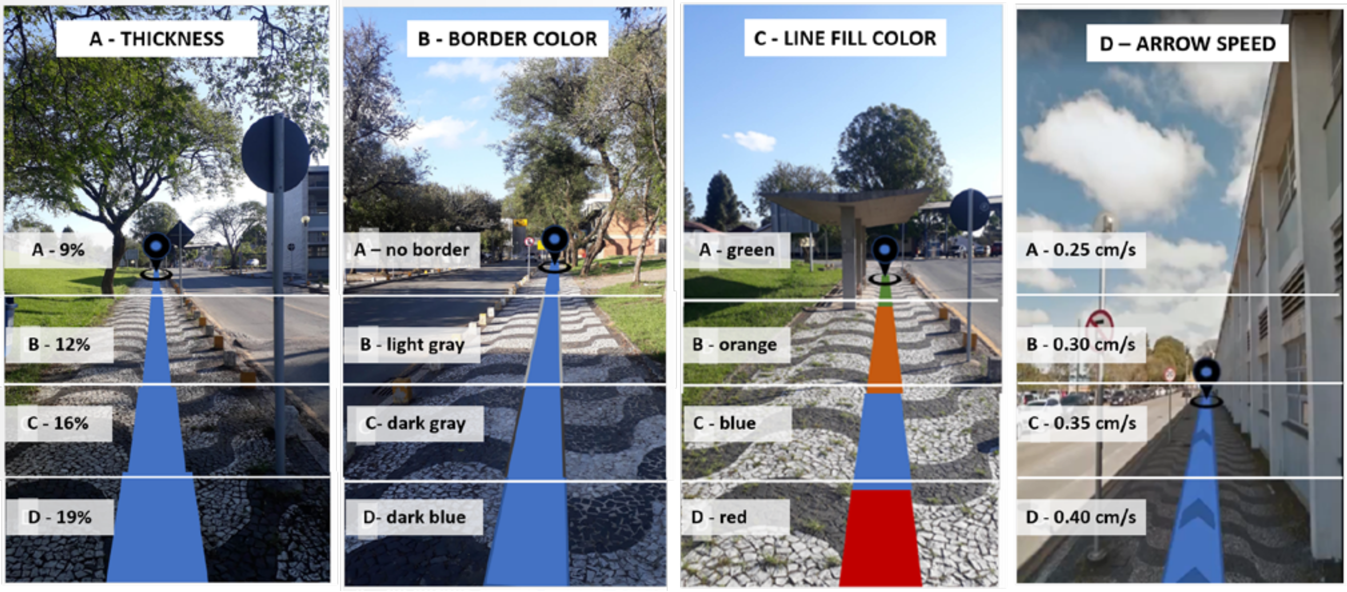

Figure 1: Scenarios of the experiments with the overlapping of the design of symbols to represent routes.

2.1 Experiments

This research employed questionnaires to profile the participants and gather responses from experiments, accompanied by the utilization of the Think Aloud protocol. For all tests, participants were presented with the Free and Informed Consent Form and the terms outlining the usage and recording of audio and video during the experiment. The research adhered to ethical standards by submitting all protocols to the Research Ethics Committee at UFPR (Proc. 142253/2020-0) through the Plataforma Brasil system. The recordings and questionnaires serve to capture users' impressions and verbal expressions while interacting with the interface during the tests. The participant characterization questionnaire comprised both open and closed questions, addressing participants' experiences and the frequency of utilizing paper maps, online maps, and Augmented Reality (AR) for navigation tasks. Additionally, it collected information regarding formal educational levels and ophthalmological characteristics. The participant characterization and term-signing process took approximately 5 minutes.

To conduct the research experiments, two random groups were formed, each one consisting of 10 participants. The distinguishing factor between the groups was the order task employed to visualize the scenarios, the order of presentation of the representations in each task was the same among the groups. The test scenarios at the Federal University of Paraná - UFPR, involved observing the AR display on a smartphone and selecting the most suitable symbol design to represent a route line to its destination, presented in AR. Four stages evaluated the proposed cartographic symbology in terms of its semantic and legibility aspects, considering graphics, relative contrast, positioning, and other variables. Before commencing each stage, the experimenter verbally explained the task for approximately 30 seconds. The average time to complete the four stages, including the explanation segment, was approximately five minutes, with variations of up to one minute.

2.2 Participants

A cohort of 20 volunteers, randomly selected, participated in the experiments, comprising 8 men and 12 women. The participants had an average age of 30.2 years (minimum = 25 years; maximum = 44 years; standard deviation = 5.5 years). In terms of educational background, 10 participants held undergraduate degrees, while the remaining 10 had master's degrees, all in Cartography or related fields. The collection of ophthalmological characteristics revealed that 16 participants did not use glasses, while 4 had myopia or astigmatism, necessitating corrective glasses.

To gauge participants' knowledge of using paper maps for navigation, 80% (16 participants) reported utilizing such representations, particularly for road trips, touristic maps, and educational resources. Concerning the experience with paper maps to perform navigation tasks, 20% of participants claimed a low level, 60% a medium level, and 20% a high level. All participants reported previous use of digital maps, primarily for short walks, trips, exploring unfamiliar locations, estimating time taken to travel a route, and determining directions. Regarding experience with digital maps, 10% reported a medium level, and 90% indicated a high level. Experience levels with AR indicated that 10% had no prior experience, 50% had low experience, and 40% had medium experience. Augmented Reality (AR) usage encompassed applications like social media filters, plant and object identification, gaming, QR codes, and product visualization. The level of experience in the use of AR indicated that 10% had no prior experience, 50% had low experience, and 40% had medium experience.

3. Results

3.1 Evaluation of the line thickness to represent the route

In selecting the most appropriated line thickness to represent the route, four incremental options were considered, the first at 9%, followed by 12%, 16%, and 19%. Task results revealed that twelve users (60%) opted for the 9% thickness, while eight users (40%) selected the 12% thickness. None of the users chose the 16% or 19% thickness. Descriptive statistics pertaining to the choice of the best thickness indicated an average of 1.4 and a standard deviation of 0.505, this suggests higher preference for the smallest thickness among participants. Concerning the number of times participants observed all options (number of glances) to decide the most appropriate option, 40% (8 users) made their selection after one glance, 20% (4 users) after two glances, 30% (6 users) after three glances, and 10% (2 users) after four glances. The mean number of times to observe was 2.1, with a standard deviation of 1.08, highlighting that participants typically needed one or two times observing to make the choice for the task. On average, users spent 25 seconds making this decision, with a standard deviation of 6.9 seconds, and minimum and maximum times of 13 seconds and 35 seconds, respectively. Examining data distribution, values for choosing the best thickness, the number times to observe and the time of choice exhibited no outliers, and the datasets conformed to a normal distribution (p-values > 0.100) according to the Shapiro-Wilk test.

Figure 2 provides a graphical summary of the statistical analysis for this task. The boxplot (Figure 2a) illustrates that the first thickness (9%) required fewer glances and a shorter time for selection, while the second thickness (12%) required a wider variation in the number of glances and an extended observation time. The frequency histogram (Figure 2b) with all answers, complemented by a line of normal distribution, suggests a propensity for a low number of glances and an inclination towards an extended observation time.

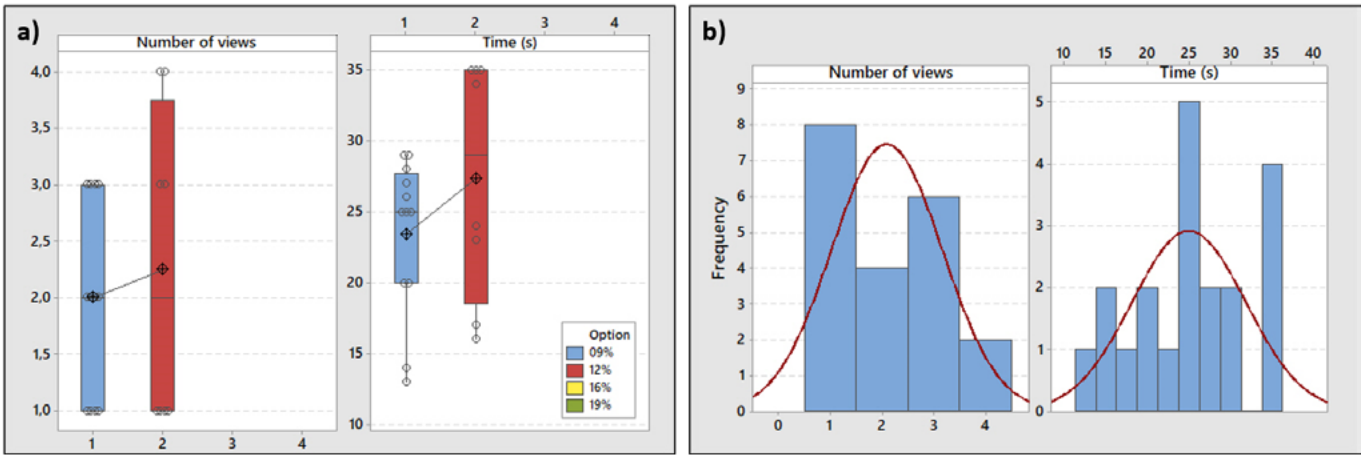

Figure 2: Graphic Summary for the thickness of the route: boxplot (a) and frequency histogram with normal distribution (b).

The feedback provided by participants in the experiment pertaining to the depiction of line thickness in the route was subjected to analysis. In general, predominant observations underscore that the thickness of the route line exerts an influence on the number of elements discernible within the landscape. Furthermore, it was noted that line thickness can impact the perception of the object's morphology. The utilization of a thinner line thickness appeared to enhance the perception of the surrounding scenery, potentially facilitating more assured navigation. It was observed that the thickness of the line extends over the image, thereby affecting the segregation between figure and background. This phenomenon results in the partial occlusion of the image and obstacles along the route, as indicated by several comments. Consequently, lines with greater thickness contribute to increased obstruction. Lines of either excessively thin or thick dimensions pose challenges in terms of visualization. Thinner lines afford a greater contextual view and facilitate easier observation of surrounding objects, while thicker lines tend to dominate the visual representation. An additional consideration is that the destination position was centered within the image, but in practical applications, the user has the flexibility to alter this position while navigating the environment. Consequently, variations in line thickness may exhibit considerable variability. The insights gathered during the task execution are presented in Table 1.

Table 1: Summary of participants' comments for the task of selecting route thickness

Comments
The smallest thickness does not take up much space on the screen
Too small makes it more difficult to view because it is thinning. When it increases, if it is too large, the beginning and end of the route are very different. The notion of tapering is greater with greater thickness, it seems that it is going on.
The greater the thickness, greater the discomfort and the feeling of covering the space to be followed and that there may be a covered obstacle.
Thinner routes show more the representation context. Thicker routes seem to be the only element represented.
Smaller thickness allows visualizing and locating surrounding objects more easily.

3.2 Evaluation of the route border-color

The design of the route border-color was conceived to allow for the selection of four distinct color hues: no border-color or with the same filling color (RGB: 68; 114; 196); light gray (RGB: 167; 167; 167); dark gray (RGB: 67; 67; 67); and dark blue (RGB: 47; 86; 154). The route border-color options analysis revealed that the participants chose all alternatives. Specifically, 8 participants (40%) opted for the first choice (no border-color), 6 participants (30%) favored the second option (light gray), 2 participants (10%) selected the third option (dark gray), and 4 participants (20%) chose the fourth option (dark blue). The examination of the number of glances taken to determine the optimal route border-color indicated that 6 participants (30%) made a single observation and reached a decision, while 10 participants (50%) required two glances and 4 participants (20%) engaged in three observations. On average, participants needed 2.1 glances to make the best color selection, with a standard deviation of 0.7 glances. In the overall context, participants spent an average of 16.7 seconds, with a standard deviation of 5.6 seconds, to complete this task, ranging from a minimum of 10 seconds to a maximum of 25 seconds.

Concerning the distribution of data, no outliers were observed for the values associated with choosing the optimal route border-color, the number of glances, and the time taken for the decision (Figure 3). The datasets conformed to a normal distribution (p-values > for choosing the option and number of glances, p-value = 0.069 for time) based on the Shapiro-Wilk test. Figure 3 provides a graphical summary of the statistical analysis for the route border-color selection task. The boxplot (Figure 3a) indicates that the first border-color (no border) prompted a higher number of glances, along with a more extended observation time. The second (light gray) and fourth options (dark blue) exhibited a comparable number of glances, with the fourth option demonstrating a shorter observation time and lower variability. The frequency histogram (Figure 3b), with a normal distribution line, suggests symmetry for the number of glances and heterogeneity for the observation time of the task.

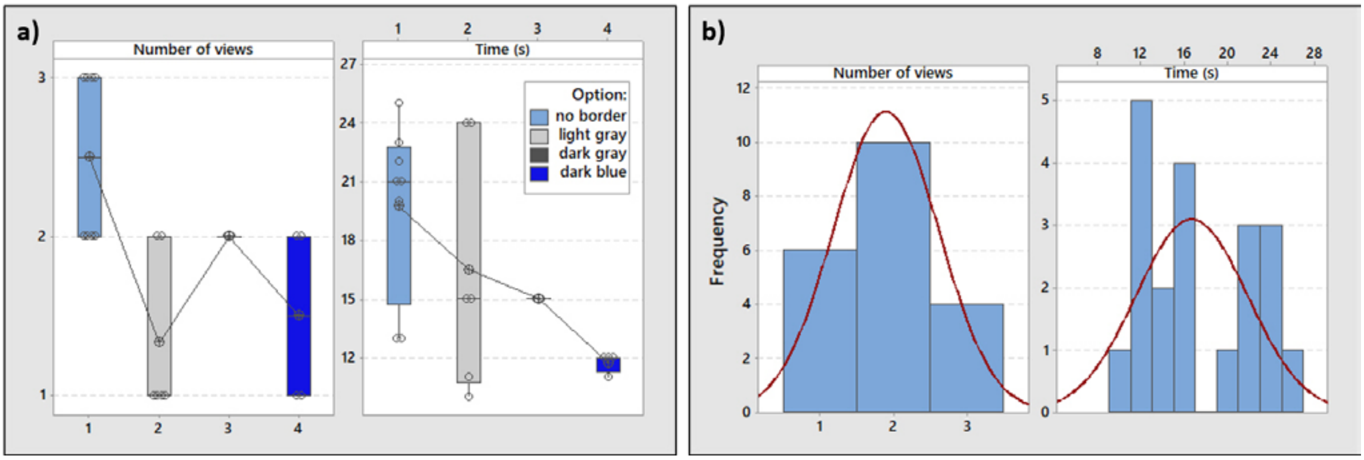

Figure 3: Graphic Summary for the route border-color: boxplot (a) and frequency histogram with normal distribution (b).

Table 2 provides an overview of the analysis conducted on the feedback from participants in the experiment pertaining to the representation of the route border-color. Overall, predominant comments underscore a preference for the blue hue, the option without a border-color, or the option featuring a gray border-color. Participants expressed a preference for the blue border-color, citing its visual comfort and suitability as a symbol for the route. Furthermore, it was observed that the use of dark-gray or white border-color may reduce the legibility with other elements in the image, particularly the sidewalk pavement. Participants generally perceived the route symbol as visually pleasing and more harmoniously integrated with the overall image. The addition of a light-gray border-color was noted to enhance contrast and perception, while the use of distinct hue for the line fill and border-color could contribute to an improved visual aesthetic.

Table 2: Summary of participants' comments for the task of selecting the color of the route line.

Comments
Without a border-color it seems more united with the image, the other colors seem to be a separate object. The other colors contribute with the three-dimensionality
The black like is similar to the end of the route symbol, white presents a lot of contrast. Without a border-color is simple.
Without a border-color it is already possible to visualize the route and understand its reason. With a border-color, the sense of reality is diminished and it loses the feeling of being a path, looking like a drawing and losing its three-dimensionality.
The gray border-color increases the contrast and improves perception. Two hues look best, one of the lines and one of the edges.
The gray border-color stands out more, the others are not very perceptive and do not attract attention.

3.3 Evaluation of the route line color fill

The initiative for color hue selection in filling the route line involved the consideration of four color hue options, green (RGB: 84; 30; 53), orange (RGB: 197; 90; 17), blue (RGB: 68; 114; 196), and red (RGB: 192; 0; 0). In determining the most appropriate filling color hue for the route line, participants chose for the orange hue on 6 occasions (30%), the blue hue was chosen 10 times (50%), the red hue received 4 selections (20%). Among participants, 20%

(4 individuals) made their choice after a single glance, while 50% (10 participants) required two glances, and 30% (6 participants) engaged in three glances. On average, participants required 2.1 glances to complete the task, with a standard deviation of 0.718. The collective time expended to select the best route color averaged 19.1 seconds, with a standard deviation of 7 seconds, and a range from a minimum of 10 seconds to a maximum of 34 seconds.

No time values were identified as outliers and all datasets adhered to the normality curve with p-values lower than 0.100 in the Shapiro-Wilk test. Figure 4 presents a graphical summary along with the statistical analysis of the results derived from the task of selecting the route line color fill. The boxplot (Figure 4a) indicates that the second (orange) and third (blue) options for route line color fill exhibited a lower number of glances and observation time compared to the fourth option (red). Additionally, the second option (orange) displayed high variability, while the third option (blue) showed low variability. The frequency histogram (Figure 4b), complemented by a normal distribution line, suggests symmetry for the number of glances and heterogeneity in the observation time for the task.

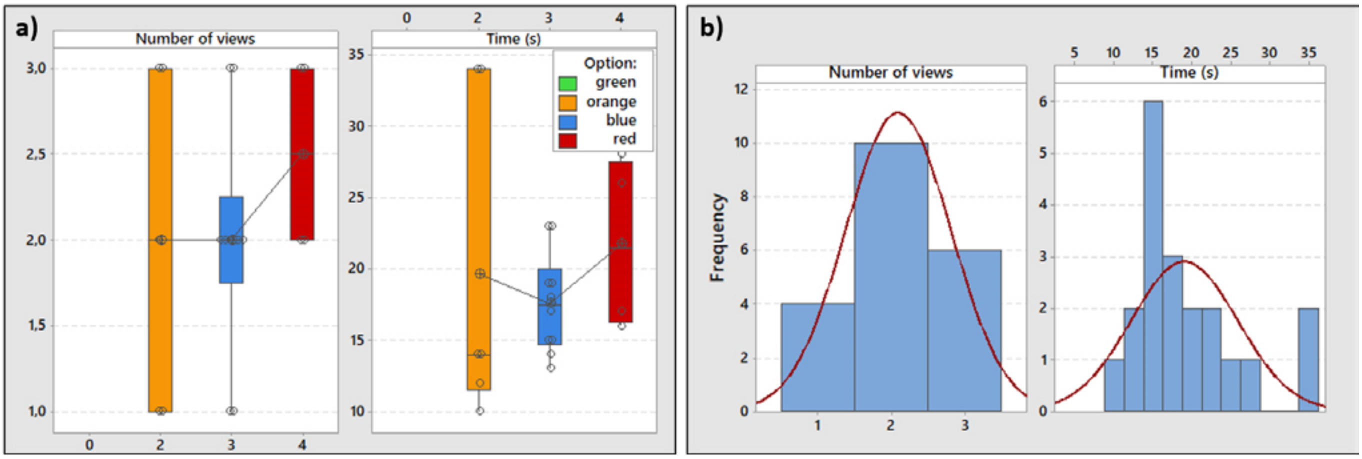

Figure 4: Graphic Summary for the route line color fill: boxplot (a) and frequency histogram with normal distribution (b).

Table 3 provides insights into participant comments, particularly concerning the semantics involved in selecting the route line color fill. Notably, preferences varied among participants, with some favoring the blue hue due to its common usage in navigation applications and its non-fatiguing impact on vision. In contrast, others expressed a preference for colors hues like orange and red, citing their heightened visibility and ease of perception. Concerns were raised about potential confusion with the green hue, often associated with vegetation, and the possibility of the blue color blending into the sky. On a broader scale, it appears that traditional colors for representing routes in road systems lean towards red and orange. However, the diversity of preferences and approaches suggests new possibilities for route line color fill. The paramount consideration is the selection of a color hue that facilitates easy identification and assists users in following the route safely and efficiently. Furthermore, contextual relevance is crucial, emphasizing the importance of choosing a color hue that harmonizes with the visual elements of the image, such as the asphalt in the street. This nuanced approach ensures a seamless integration of the route line within its presented context.

Table 3: Summary of participants' comments for the task for choosing the route line color fill.

Comments
All colors are good to represent the route, blue does not tire the eyes and it looks like what the applications already represent.
Prefer the blue because the red/orange is very discordant, very flashy. The blue matches more with the proposal. It is possible to confuse green with vegetation and it does not harmonize.
The blue color is more common for representing routes. The green can be a problem in places with a lot of vegetation, orange is too flashy, red is usually used for cycling routes.
The blue can blend with the sky, the green can be confused with the grass. Red and orange are more traditional colors to represent paths in road systems, preferable.
The red color stands out among the others, attracts more attention and facilitates perception.

3.4 Evaluation of the arrow speed over the route line

The fourth task involved selecting the most appropriate speed for the animation of an arrow along the route, a crucial aspect in guiding the map-reader to proceed along the indicated path. The design offered five options for the speed of arrow movement over the route line: 0.25 cm/s (slow), 0.30 cm/s, 0.35 cm/s, and 0.40 cm/s (fast). Results from this task indicated that 12 participants (60%) chose the first speed (0.25 cm/s), 2 participants (10%) opted for the second speed (0.30 cm/s), and 6 participants (30%) preferred the third speed (0.35 cm/s). The higher speed, represented by the fourth option (0.40 cm/s) was not selected. The average speed preference was 1.7, the median was 1, and the standard deviation was 0.9.

In selecting the optimal arrow speed, 10 participants (50%) made their decision after a single glance, 2 participants (10%) required two glances, and 8 participants (40%) engaged in three glances. On average, participants glanced the representations 1.9 times to complete the task, with a standard deviation of 0.9. The average glance time for the representations was approximately 26.2 seconds, with a standard deviation of 10.7 seconds. The shortest glance time recorded was 10 seconds, while the longest was 49 seconds. No glance time values were identified as outliers and all datasets conformed to the normality curve, with p-values lower than 0.100 based on the Shapiro-Wilk test. Figure 5 presents a graphical summary alongside the statistical analysis of the results derived from the task of selecting the arrow movement speed over the route line. The boxplot (Figure 5a) indicates that the first speed option exhibited a smaller mean in the number of glances and a shorter glance time, accompanied by greater variability. The frequency histogram (Figure 5b), complemented by a normal distribution line, suggests asymmetry in the number of glances and heterogeneity in the glance time for the task.

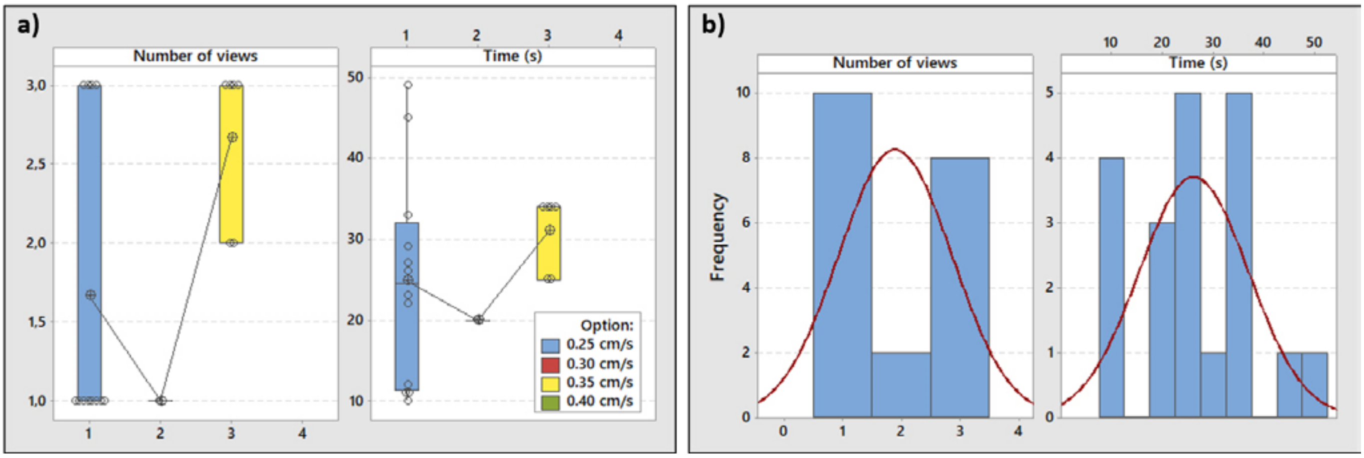

Figure 5: Graphic Summary for the route filling color: boxplot (a) and frequency histogram with normal distribution (b).

Participants were queried regarding their preference for visualizing a route with or without overlapping directional arrows. Of the respondents, 16 participants (80%) expressed a preference for the presence of animated arrows, while 4 participants (20%) preferred the inclusion of static arrows. The participants reported certain visual disturbances when confronted with variations in the speed of the arrows along the line route, as perceived in Table 4. Some participants highlighted the utility of arrows for individuals unfamiliar with the spatial layout of a location, emphasizing their clarity in indicating the direction to follow. However, concerns were raised about potential confusion, particularly when arrows are in motion, as they fail to account for natural variables such as the user's walking speed. Optimal visualization, it was suggested, may involve stationary or slow-moving arrows to simplify the viewing experience and prevent distraction for observers.

The utility of moving arrows was acknowledged, particularly in guiding turns, where it could attract participants' attention and provide advanced indications of forthcoming maneuvers. However, a crucial consideration is striking a balance between furnishing sufficient guidance without overwhelming users with excessive visual stimuli. In summary, the deployment of arrows can serve as a valuable tool for guiding individual's attention along a path or route. Yet, their careful use is paramount to ensure they augment rather than detract from the viewer's overall experience. Achieving this balance is essential to harness the full potential of arrows as effective navigational aids.

Table 4: Summary of participants' comments for choosing the arrow speed.

Comments
The arrow represents the direction, helps people who do not have spatial knowledge of the place. If it is too fast it may get in the way of seeing the location, it could increase speed as it approaches the destination.
As the speed of the arrow increases, it confuses the perception and "gives it a bug" in the head. The presence of arrows confuses the interpretation as it does not indicate a natural variable (e.g.: speed). In case the arrow was still, it would be better.
With arrows it is better to understand the route, as long as they are still or with little movement. The increase of speed causes a feeling of having to walk faster, feeling of pressure.
The movement of the arrow will help especially when making turns, it can indicate in advance what the next move will be. Moving the arrow too fast causes confusion.
Arrow speed seems to correlate with walking steps, so median speed makes more sense. The moving arrow is preferred for the sense of continuity as you follow the path.

4. Conclusion

This research aimed at designing and evaluating static visual variables (thickness and color hue) and an animated visual variable (speed) in the representation of routes for personal navigation tasks supported by Augmented Reality. To this end, an experiment was conducted involving four map-reading tasks with AR to evaluate fill color, border color, and route line thickness, as well as the application of speed to arrows overlaid on the route line.

The primary objective of the first task was to identify the best line thickness for representing a route on a map among four options. Results pointed that users chose the thinnest line, which corroborates with the number of glances and time spent in decision-making. Participants noted that thinner lines facilitated better perception of surrounding scenery and improved navigation. In the second task, participants selected a border-color for the route from four options and the preferences varied, but no border-color and light-gray were the most popular. The comments pointed to the importance of the edge of the line for the figure-ground segregation of the route with the real environment viewed by AR.

In the third task, participants chose the best fill-color for the route line, the blue hue was chose as preferred, but diverse preferences highlighted the need for easily identifiable colors that harmonize with the visual elements. The final task involved determining the appropriate speed for an arrow moving along the route, with participants viewing arrows moving at various speeds from slow to fast, the results showed that lower speed was chosen the best option. The use of moving arrows is valuable for guiding turns and attracting attention to forthcoming maneuvers, but it is crucial to balance providing sufficient guidance without overwhelming users with excessive visual stimuli to ensure they enhance the navigational experience.

Based on the findings, future studies could delve into investigating the relationship between route line thickness and perceived distance during navigation. Psychological and emotional analyses of route line colors, exploring their impact on user confidence and experience, could also be a promising avenue to ensure that the information is easily comprehensible and does not overwhelm the user, thereby enhancing navigation efficiency and effectiveness. Additionally, examining color preferences in different contexts of use and evaluating cognitive effects associated with varying arrow speeds along the route would contribute valuable insights. Conducting additional studies with a larger sample size may help validate the findings of the research and comparative studies among different countries or cultures may shed light on variations in preferences and perceptions of route representation elements.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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AUTHOR´S CONTRIBUTION

All authors contributed equally.

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