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Web-based Measurement of Directional Bearings (Angular Distance)

by Ashley H Oiknine, Benjamin T Files, and Kimberly A Pollard

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14. ABSTRACT Evaluating performance on spatial-related training and tasks such as search and rescue necessitates ways of measuring spatial knowledge. While most spatial assessments have straightforward implementations, directional bearings present a challenge in administration and preprocessing. In paper and pencil assessments, scoring and inputting these data are time-intensive and prone to human error. Customized computer programs mitigate the scoring and data input issue through automation but are costly to build and challenging to integrate in experiments with other assessments. Thus, a low-cost solution that automates data input and scoring, while also integrating with other assessments, was deemed valuable. In this report we discuss previous measurements of directional bearings and outline the criteria and inspiration for a solution. Next we describe detailed instructions to implement our solution that leverage functionalities using Qualtrics software. Then we discuss limitations and future directions for the directional bearings measurement tool.					
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Summary

Many spatial tasks are important for US Army goals, for example, for mission training scenarios involving search and rescue, wayfinding in novel terrain, and extracting high-value targets. Evaluating performance on spatial-related training and tasks necessitates ways of measuring spatial knowledge. There are three main stages in spatial knowledge acquisition: landmark, route, and survey knowledge (Siegel and White 1975; Stern and Leiser 1988). Some early spatial knowledge research relied on paper and pencil methods to evaluate retained spatial knowledge during free recall tasks, route description (Lovelace et al. 1999), and directional bearings (i.e., spatial orientation, relative distance, and angular distance) (Wender et al. 1997).

Tasks such as landmark recall and route description have straightforward digital implementations (e.g., text boxes in user-friendly survey platforms such as Qualtrics). However, indicating the directional bearings of an object given an orientation has a less straightforward implementation. Some examples involve having a participant physically point to the target given a starting object and orientation, while others use paper and pencil diagrams on which participants indicate directional bearings (e.g., a circle with N, S, E, and W). Paper and pencil tasks, although useful, come with a high data-processing cost. In much of today's research, most tasks are completed digitally through custom programs (Rothkegel et al. 1998; Ragan et al. 2017) or involve specialized hardware with tracking (Waller and Hodgson 2006). These customized programs can be costly to build and are generally used in studies strictly investigating directional bearings. With more-advanced investigations involving many variables, tasks, and measurements, there is an increasing need to integrate these measures with other experiment tasks and questionnaires onto (preferably) one platform for seamless and efficient data collection with minimal preprocessing. One tool that has been at the forefront of this need is the Qualtrics survey platform. Qualtrics has a slew of capabilities that can be creatively adapted to meet such a need. Here we describe a novel use of the Qualtrics platform for directional bearings input. This method is low cost and user friendly, and it requires minimal processing. We provide the inspiration for the question wording and formatting (Ragan et al. 2017), describe steps taken to integrate the questions with the Qualtrics platform, and discuss various validation considerations and limitations.

1. Introduction: Spatial Knowledge and Angular Distance

Evaluating spatial knowledge is important for understanding performance in spatial tasks. There are varying levels of spatial knowledge and a variety of ways to measure them. In the following we discuss directional bearings as well as various methodologies that measure them.

1.1 Directional Bearings

Relative directional bearings is an aspect of spatial knowledge that reflects the relative angular distance of an object or landmark given a starting orientation (If at A, facing B, where is C?). Such knowledge may be referred to as judgments of relative direction, angular distance, headings, azimuth, or relative angular direction (e.g., Fields and Shelton 2006). There are many ways to measure directional bearings from human subjects, including physical pointing tasks or indicating directions on a circle with anchor values (e.g., cardinal directions or 0°–360°).

User pointing requires an experimenter to manually record the user response, or it requires use of a sophisticated body position tracking system such as motion controlled virtual reality systems, or gyroscope-containing swivel chairs and laser pointers (e.g., Henry et al. 2009; Pino et al. 2013). High-tech methods with multiple moving parts raise the risk of malfunction, and those requiring integrated physical lab facilities are not practical for most researchers. Manual recording has its own issues of scorer reliability, interpretation, and human error across experimenters. This also involves transcribing potential written data and/or risks error in data input. Some researchers have developed hardware (clicker pointers with inertia cubes attached) to mitigate this issue (Waller and Hodgson 2006); however, in a large-scale study this may take more time to calibrate and administer, especially if there are multiple prompts.

Another example is the paper and pencil measure of bearings. In one administration of a paper and pencil study, participants were presented with a circle that had cardinal directions and were asked to indicate relative direction of an object by writing the cardinal directions for the sector the target was located in (Wender et al. 1997). An advantage to this method is that it is quick to administer and intuitive to understand. Unfortunately, it also requires manual data entry, which is prone to human error and costly in amount of time needed to score (especially with multiple questions and participants). Additionally, this specific method could be problematic depending on the level of granularity needed in the response to answer

the bearings question. Cardinal values (e.g., N or NE) are less detailed than degree values (e.g., 360, 330, or 300).

Ultimately, the design of the measuring tool used will depend on the overall design of the experiment, the resources available, and the research question. In the following we describe the need for a brief measurement of bearings in the context of a large within-subjects investigation involving many tasks, questionnaires, and other assessments of spatial knowledge.

1.2 Motivation and Criteria

A need for a directional bearings test arose in the context of an experiment to evaluate differences in acquired spatial knowledge while accounting for individual differences and various immersive mediums. In that study, multiple transfer tasks were designed to evaluate acquired spatial knowledge. These included object recall, object recognition, route description, and directional bearings, among others. While some spatial tasks had straightforward implementations, angular distance measurement presented a challenge. The selection criteria we used were that the directional bearings measure should be presented seamlessly with the other questionnaires and tasks, have minimal programming requirements, be quick to administer, be intuitive to users, and have had a low data-processing cost.

1.2.1 Qualtrics

Qualtrics survey software is a widely used and US Department of Defense–approved survey platform that can create and deploy questionnaires with a myriad of capabilities. While a discussion of the range of their services and affordances is beyond the scope of this report, Qualtrics has various built-in question templates to help create a survey quickly. Due to the design of our overarching experiment, there were a large number of survey questions and other transfer tasks that needed to be included in one platform. Qualtrics’ affordances such as back-end scoring, skip logic, and other adaptable tools made the platform ideal to meet these project needs. Therefore, integrating the directional bearings questions in Qualtrics was advantageous for streamlined data collection (i.e., not having to exit the platform to launch a separate program or add an experimenter engagement with the participant to record behavior).

1.2.2 Programming

Another criterion was the minimal programming effort. Due to the number of questions we needed, it was valuable to create a measurement with minimal programming. In Qualtrics, we were able to program one template question and

duplicate that question in a way that retained all of the logic, selectable areas, and validation criteria. This template question was used to change out object images to generate 36 separate directional bearings questions for our study. This procedure was less time-consuming than building a stand-alone program to measure and process directional bearings.

1.2.3 Quick Administration

We wished to present each participant with 36 bearing questions over the course of three sessions, which meant that it would be advantageous if the questions did not take a long time to administer. In previous work, researchers have used gestures within an environment or a paper compass to report bearings. Given the scope and overall time to execute the main study's design, a short computerized administration of directional bearings was ideal.

1.2.4 Intuitive

It was important that the administration of the bearings question was intuitive to the participant. Because of the amount of additional tasks participants were asked to complete during the sessions, we wanted to minimize time spent on complicated instructions. We also wanted to avoid participants asking clarifying questions to the experimenter to avoid any differences across participant sessions. We used an example question that walked participants through the process of answering the bearings question with corrective feedback and instructions on Qualtrics. This example question with corrective feedback ensured all instructions and error corrections to be uniform.

1.2.5 Minimal Data Processing

Some of the other options such as handwritten bearings questions or manual recording of behavioral/verbal responses imposed a high data-processing cost. Implementing a digital version through Qualtrics that stored participant degree responses was an important feature to minimize processing cost and mitigate human transcription errors.

2. Proposed Solution

2.1 Inspiration

The current work adapted a computer-based directional bearings test used in a head rotation experiment (Ragan et al. 2017). This test (see Ragan et al. [2017] for image) featured the text: "Imagine that you are at the (starting object) and you are

facing the (facing object). In what direction would you find the (goal object)?" Above the text was a large circle with a "starting" object placed in the middle of the circle and an arrow pointing toward a picture of the "facing" object above the circle. On the circle was a red marker that participants were able to position at any point along the perimeter of the circle with a mouse.

2.2 Our Bearings Task

The differences between our bearings test (Fig. 1) and that of Ragan and colleagues involved a small change in the text phrasing and degree intervals, and it removed the arrow. For the text, we changed the first phrase to read "Imagine you are *standing on (the starting object)*". This was done to mitigate any inconsistency across participants in their interpretation of the prompt. All participants may not "imagine being *at* an object" the same way. For example, one could envision "at" as being to the right or left of the starting object, which may skew their response. By standing "on" the object, participants may be able to visualize the starting place more consistently. The orientation test by Ragan et al. (2017) did not display the degree values or distinct intervals. Instead, their computer-based tool allowed for the entire range of degrees to be a potential input. For our bearings test, we had tick marks represented along the circle with intervals of 6° from 0° to 360° . This was done to present anchoring degrees that participants may be familiar with and to adjust their responses accordingly (e.g., knowing exactly where 90° is or a little more/less). Additionally, this allowed us to collect discrete degree responses through Qualtrics. Then we removed the arrow between the "start" object and "facing" object because it was difficult to predict whether participants would pay more attention to the arrow or the instruction. For example, if the arrow is facing a particular orientation of the "facing" object, it might distract participants into visualizing where the object is relative to the "facing" object orientation rather than visualizing the environment in their mind's eye to derive the appropriate orientation, and it might encourage participants to click tick marks near where the arrow is pointing.

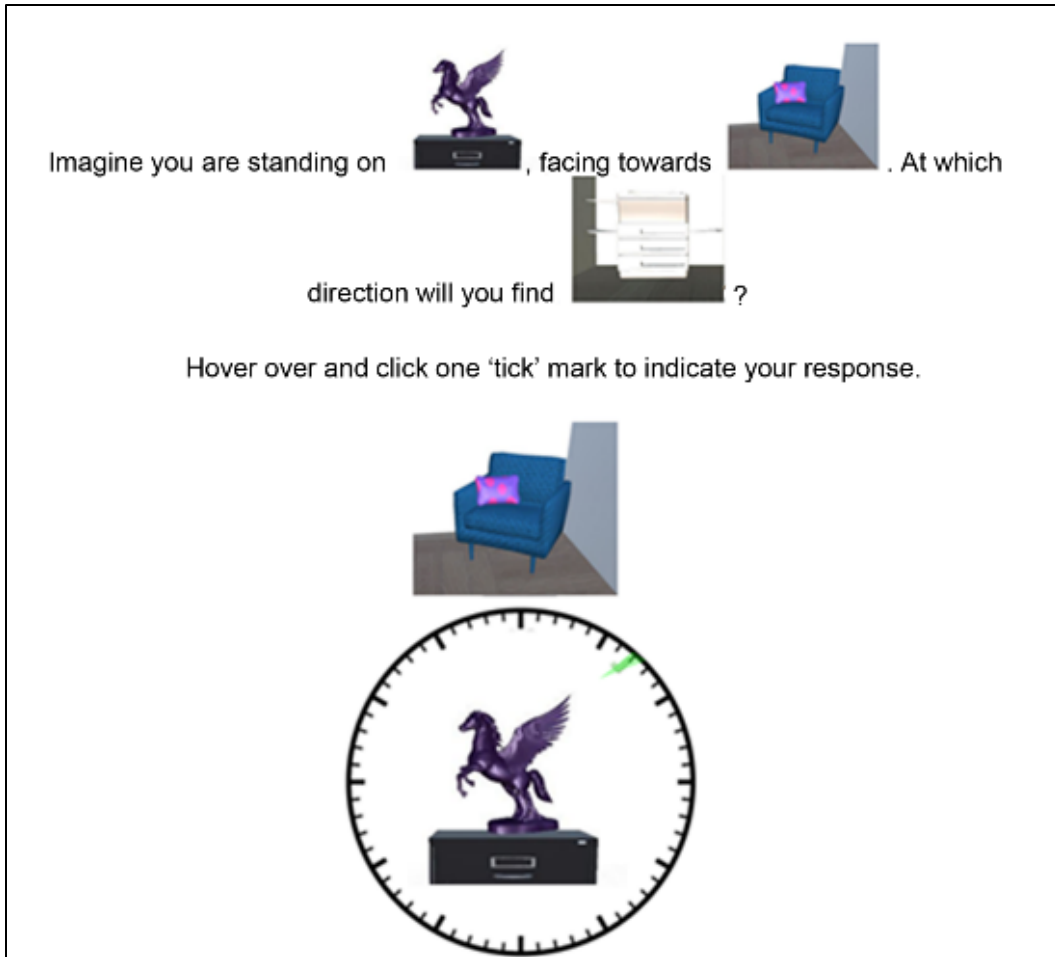


Fig. 1 Adapted bearings test, simulated participant view

3. Creating the Template

3.1 Image Creation

To generate many question images for our task, we created a PowerPoint document with an image of a clock (Fig. 2, Phase 1). An analog clock face was ideal since it had equidistant tick marks and clearly indicated angles that most are familiar with (0° , 90° , 180° , etc.) with a high degree resolution of tick marks in between (intervals of 6°). Participants might also be familiar with using clock directions to describe directional bearings in everyday life. Next we removed the numbers and clock hands to yield a blank template with only the circle and respective tick marks remaining. Then the image of an object (to indicate the location where the user is to imagine standing) was placed in the center of the circle and the image of an object (to indicate where the user is to imagine facing) was placed directly above the circle (Fig. 2, Phase 3). This template was then saved and reused for each set of

object images per each bearings question for uniform and efficient generation of test images. Once all of the images were created for each of the bearings questions, they were saved in a Qualtrics-friendly format (e.g., jpg) and uploaded to Qualtrics.

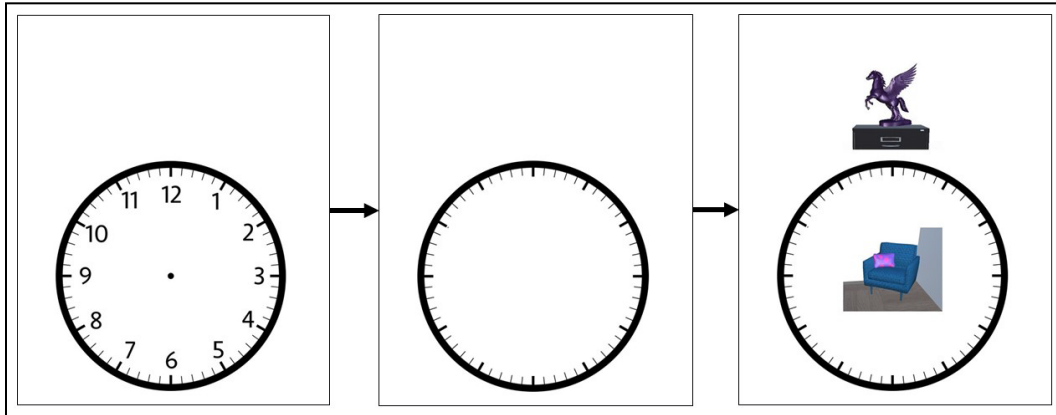


Fig. 2 Bearing question template creation; (left to right) Phases 1, 2, and 3

3.2 Prompt Creation

Within a Qualtrics project, the top of the page contains a default question block. Once you select this question, a survey menu toolbar on the right side of the screen pops up with the first drop-down titled “Change Question Type” (Fig. 3). We used the drop-down menu to make sure that the “Text/Graphic” question type was selected and then entered the prompt text. For our study, we used the following text: “Imagine you are standing on (start image) facing towards (facing image). At which direction will you find (target image)?” After entering the text, the tab directly above the text box titled “Rich Content Editor” was used to select the picture icon to specify the image and its dimensions. Once we created the prompt, we added a new question by hovering over the block and selecting the lower of the two green circles with a (+) sign.

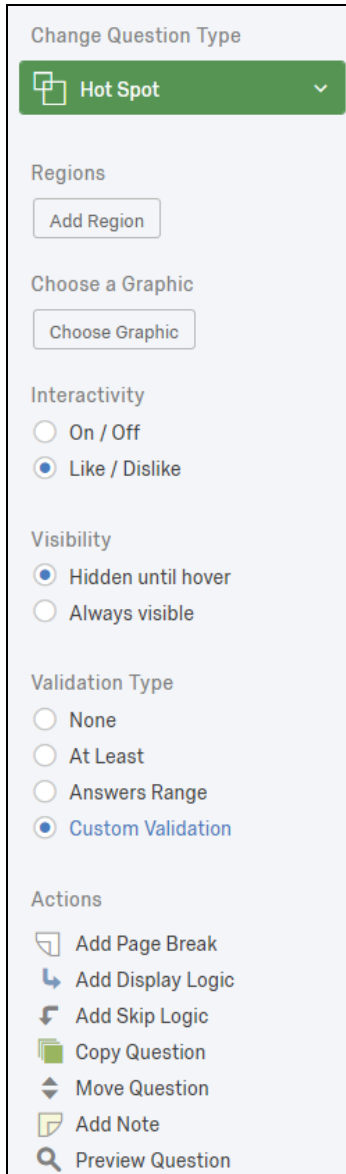


Fig. 3 Survey toolbar

3.3 Hot Spot as a Bearing

We used the “Question-Type” drop-down menu to select “Hot Spot”. Once we selected the “Hot Spot” question type, we selected the uploaded bearing image we created (see Section 3.1, Image Creation). The “Hot Spot” question type was designed to inform survey creators about participant responses to areas in an image (e.g., advertisement), such as which areas of an ad are “liked” and “disliked” in a marketing study. We used this feature of the “Question-Type” to create tick marks along the circle. On the same panel as Question-Type, located on the right-hand side under the heading “Regions”, “Add” region was used to outline

each individual tick mark. Next, a standard square shape with an associated label field was used. For the 0° , 90° , 180° , and 270° tick marks, we resized the rectangle to fit around the tick mark, keeping in mind to save room for surrounding tick mark regions (Fig. 4, left). For the remainder of the tick boxes, we used a triangle shape to border the tick marks. We then right-clicked the new added region, selected “Edit Shapes” and removed one corner of the added square region by selecting “remove one point” to create a triangle. Next we resized the triangle to fit around the remaining tick marks. Once we had the shape, we cloned the triangle as many times as was needed. Some tweaking was done depending on the angle of the tick mark. After resizing, we entered the degree value in the label description, which enabled us to identify what selection participants made in the data output. Once we completed all tick marks and labels, we set the “Interactivity” in the toolbar to “Like/Dislike”. For “Visibility”, we choose “Hidden until hover” because we believed the clock tick marks were more intuitive and the colorful tick boxes may have been distracting (see Fig. 1 for participant view).

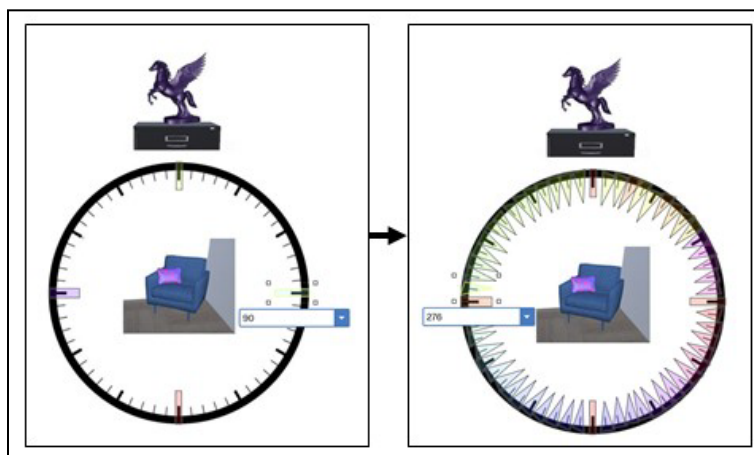


Fig. 4 (left) Rectangle and (right) triangle regions with degree value labels

3.4 Set Validation Criteria

Next, to ensure that users only select one region, we used the “Custom Validation” feature under the “Validation Type” in the survey toolbar to restrict users to one response. After this feature was selected we inputted the following settings (Fig. 5). The first field contained the bearings question name, the next box was set to “Like (Count)”, the third box was set to “Is Equal to”, and the fourth box was set to 1. These criteria ensured that participants could only “like” one region per question. The next validation criteria ensured that no participant could “dislike” any region (Fig. 5). Then we created an error message to present to users when they violated these criteria.

Custom Validation

Validation will pass if the following condition is met:

Q1 Click to write the question text ▾ Like (Count) ▾ Is Equal to ▾ 1 - +

Ignore Case

And ▾ Q1 Click to write the question text ▾ Dislike (Count) ▾ Is Equal to ▾ 0 - +

Ignore Case

Choose an error message to display on failure: Require single choice response ▾

Close ✓ Save

Fig. 5 Custom validation window settings

3.5 Populating

After we created the prompt question with object images using the “Rich Content Editor”, and created the bearings template with set validation criteria and error messages, we copied the pair of the questions (prompt + bearing) as many times as the number of questions we needed to generate. Then we swapped out the underlying image with the images we created in PowerPoint, leaving the hot-spot definitions, validation criteria, and error messages intact.

To upload the sample question and bearings template, visit <https://osf.io/xj9gf/>.

4. Conclusion

Although our solution offers an adaptable, efficient, and straightforward method of measuring directional bearings, it is important to note several limitations.

Qualtrics is a very useful platform. However, the platform presents its own challenges. Currently, Qualtrics’ cost is a response-count-based subscription, which requires maintaining enough response-counts in your membership whenever you wish to disseminate your Qualtrics-built questionnaire and collect/store data within the platform. Fortunately, most academic institutions retain a standing subscription to their service. Additionally, the Qualtrics data output requires some processing depending on the type of analysis software and output type (see Qualtrics documentation for differences in exported data types). Depending on the scope of your questionnaire, measuring directional bearings will add a significant

number of fields (one column per each clickable tick mark). A preprocessing solution in Excel involves using index match functions to detect the “like” across all columns and output the column header (degree value selected). The gravity of this issue varies depending on the number of added regions (tick marks) and the scope of the overall questionnaire (i.e., much more manageable if there is a low number of overall tasks and questions). In addition, Qualtrics is a web-based interface so there is always a risk in internet connectivity, changes of functionalities in future iterations of the platforms (such as removal or change to Hot Map questions), and issues of long-term data storage.

Literature is mixed in its measurement of directional bearings regarding whether an annotation/label or quantified unit (e.g., degree number) is displayed for each response to the bearings question. Some experiments use cardinal direction anchors (Rothkegel et al. 1998) while others do not (Ragan et al. 2017). It is unclear whether there are any biases to displaying anchors or its impact on performance; however, this is a question for future work to answer.

One possibly important factor for which we did not control is the specific view presented by the object images. It may be that different types of object images may have elicited varying impacts on bearing performance. For example, the image of the “facing object” could be from the viewpoint of the starting object or not, be within the context of the environment or without, or be from an average person’s line of sight (or lower or higher). It is not clear whether various image types would affect bearing performance. For the purposes of our overarching study, all participants saw all of the same questions, and only the immersive modality differed. Therefore, the impact, if any, of the images on performance can be considered noise when evaluating performance across immersive mediums. In matters where individuals are interested in understanding individual performance on bearings, understanding the role the image has may be valuable.

We have reviewed what directional bearings are in human subjects research and how they have been measured in previous literature. We have outlined the need for a straightforward, low-cost, and low-processing measurement of directional bearings. Later we described our inspiration for the solution and instruction for its implementation in Qualtrics. Then we discussed some limitations to our approach and potential avenues for further refinement. We hope this tool will be leveraged in more work to better understand spatial knowledge—particularly in the context of directional bearings. Looking toward the future, we hope to investigate that impact of varying parameters within the tool to further optimize its measurement and address some of its limitations.

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