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Abstract

Cartographic interpretation requires accurate spatial orientation. Two main sources of spatial knowledge acquisition inform spatial orientation ability: map-like perspective (map reading), and ground level perspective (wayfinding). The Pokémon GO game incorporates both types as players use a map to orient themselves while also moving around in the environment. This article presents research with university students in which the impact of Pokémon GO on spatial orientation is measured. The Pokémon GO application can offer great possibilities for planning workshops for improving spatial orientation.

Key Words: *spatial skill, spatial orientation, videogame, map reading, wayfinding.*

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Introduction

Map reading (cartography, maps, and street plans) and wayfinding (pedestrian navigation in the real world) are activities related to the skill of spatial orientation (Gonzato and Godino 2011; Irmischer and Clarke 2018). Allen (1999) discusses a growing interest in spatial skills and wayfinding in the scientific literature in geography. Spatial orientation, or the ability to physically and/or mentally orient in space, is considered to be one of the main categories of spatial skills (Tartre 1990a, 1990b; Bodner and Guay 1997). Disciplines related to geography, such as engineering, architecture, geoscience, urban planning, and geomatics, make use of geospatial information, where the spatial orientation skill is needed and enables them to work more efficiently (Kastens and Ishikawa 2006).

In geography education at the university level, numerous competencies relate to spatial orientation (Chueca et al. 2004; Ministerio de Ciencia e Innovación 2009, 2013). In Spain, where this research took place, in primary and secondary education spatial orientation is included as a topic that must be taught according to the curricular guidelines of the minimum education decree issued by the Ministry of Education and Science (Spanish Cabinet's Office 2006, 2007). Other institutions, like the National Council of Teachers of Mathematics, demand greater development of spatial orientation and emphasize the need for greater research on the teaching and learning of spatial orientation processes (National Council of Teachers of Mathematics 2000; Presmeg 2006; Battistam 2007).

Since 2009 the research group for the development of spatial skills at La Laguna University has been developing strategies and methodologies to improve the spatial orientation skill in university engineering students of the subject of cartography, students that frequently use maps, plans, and geo-referenced information. These strategies used different technologies like augmented reality, spatial data infrastructure geoportals, and a 3D render visualizer, among others.

In September 2016, at the beginning of the 2016–2017 academic year, the researchers for the development of spatial skills group gave a spatial orientation test to the second-year engineering students of the subject of cartography. The evaluation takes place at the beginning of each academic year to establish a base point for students' spatial orientation ability. The 2016 results were better than in previous years. What had happened? Given that Pokémon GO had appeared two months earlier (Pokémon GO was launched in Spain on July 15, 2016), the members of the research group decided to investigate its possible influence on students' results. The game requires use of two activities related to spatial orientation: map reading and navigation (defined as the movement from a start location to a destination in a real environment (Montello 2005). While navigating, players need to be aware of their location, and, in order to avoid getting lost, must continually orient themselves while moving toward their destination (Farr et al. 2012).

Computer games have proven to be a powerful tool for the development of spatial skills (Do and Lee 2009; David 2012). Currently much of the literature supports computer games' ability to improve spatial skills like spatial perception, spatial visualization, and mental rotation, but the research on improving spatial orientation with computer games is more limited. For example, Lin, Chen, and Lou (2014) carried out an experiment with a commercial treasure hunt game, in which the player used a map to determine the location of the hidden treasures. In that research the impact of a game-map-reading activity on the spatial orientation of the players was analyzed, but navigation task activities (wayfinding) were not performed.

Pokémon GO is a mobile (iOS and Android) application game that consists of finding and capturing characters from the Pokémon saga hidden in real-world locations. The player moves around the streets in an urban environment, represented by a map on the device screen, which shows the player geolocated on the map. This kind of game in a location-aware device allows the user to move between the virtual and the real world at the same time (Atwood-Blane and Huffman 2017).

When a Pokémon appears, one can see it on the map. When the user touches the Pokémon character, the application shows the environment from the view of the character through augmented reality. The augmented reality mode is limited to the moment of capture; in other phases of the game the player moves around the map and displays all the information in a geolocated way. The map offers the possibility to zoom, in a limited way, as distant areas cannot be viewed. This implies that it is necessary to physically depart (wayfinding, navigation) in order to visualize the environment while the map is displayed (mapping, map reading). Authors like Liao et al. (2017, 474) claim "increasing human mobility drives the need for navigation and wayfinding more effectively and efficiently." It is therefore appropriate to ask whether Pokémon GO promotes the development of spatial orientation, because while playing the game, map reading and wayfinding tasks are used intensively.

With this in mind, this article describes the results of a study on the impact of the Pokémon GO game on the spatial orientation skill of forty-seven second-year engineering university students of the subject of cartography (twenty-eight males, nineteen females, mean age 20.61 years old with standard deviation of 1.94). In order to identify other activities that may influence spatial orientation, participants completed a survey asking them how often they used geoportals, navigators, or if they had participated in orientation activities such as orientation races.

In order to contextualize the present research, results of previous research on spatial orientation are shown; this research includes a total of 469 university students who carried out different workshops specifically designed to improve the spatial orientation skill (Carbonell et al. 2011; Carbonell et al. 2015; Carbonell and Bermejo 2017). The tool for measuring the spatial-orientation skill in the present study has been the same as the one used in these previous research papers: the Perspective Taking/Spatial Orientation Test (Hegarty and Waller 2004; Kozhevnikov and Hegarty 2001).

Pokémon Go

Origins

John Hanke, the creator of the application, founded the Keyhole Company in 2001, a start-up that worked with visualization technology of geospatial data. Google acquired this technology in 2004 to launch it in 2005 as the well-known Google Earth application. Hanke led this project and its derived products: Google Maps and Street View.

On April Fool's Day 2014, Google and the Pokémon Company made the joke of hiding a Pokémon in Google Maps. The joke became so viral that it materialized in a project that in 2016 became known as Pokémon GO. The number of Pokémon GO monthly active users (2018) is 65 million (DMR Business Statistics 2018).

The Game

In Pokémon GO, real-world streets and buildings are represented in the form of a map, indicating the player's location. The game consists of capturing as many Pokémons as possible. The player, represented by an avatar, appears on the screen of the mobile device, geolocated on the map that represents the real environment where the game takes place. Pokémons, which are also associated with a geographical location, are invisible until the player is a certain distance from them, which is when they become visible and can be captured. The map can be freely rotated and the avatar rotates with it. There is a compass to orient the map in the north direction, but the usual strategy is to position the map in the same direction in which the player walks. When this action is performed the avatar walks in the same direction as the player. The map does not have street names, so the only references are the comparison between the streets in the real world and the image of the map in the virtual world. To assist in orientation tasks, the map contains some fixed elements, such as squares and contours of buildings depicted with a faint color.

Although the objective of the game is to capture Pokémons, which appear on the map in a random way, to make this capture it is necessary to visit the so-called PokeStops. The PokeStops usually coincide with sculptures, works of art, singular buildings, or emblematic places. This information provides assistance in planning routes on the map as well as serving as a visual reference.

Pokémon GO: Map Reading and Route-Based Learning

The spatial orientation skill is defined as "the ability to self-orientate relative to the environment and the awareness of self-location" (Reber 1985, 276), or "the ability to orientate physically or mentally in space" (Maier 1996, 65).

Two sources (map reading or survey learning and wayfinding or route-based learning) of spatial knowledge acquisition related to spatial orientation are presented when playing Pokémon GO. The players use the map (Fig. 1) to orient themselves (map reading) in an urban environment as they move in that environment in search of Pokémons (route-based learning).

Pokémon GO differs from many spatially oriented video games in that it uses maps to represent a real

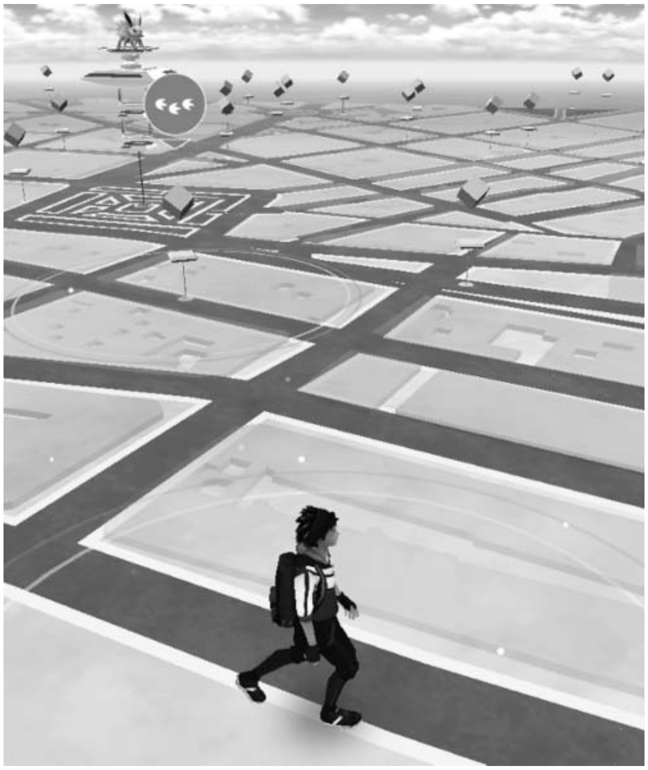

Figure 1. Pokémon GO map reading display.

environment (map reading), and, in order to visualize the environment, the player must physically move within the landscape (wayfinding), to orient themself with external references from the real world that appear on the map as the player is moving. These external references in the environment (landmarks) play a prominent role in wayfinding and localization processes (Raubal and Winter 2002), and provide a confirmation of the route during pedestrian navigation (Sorrows and Hirtle 1999). As such, Pokémon GO integrates the two main sources of spatial knowledge acquisition described by Tartre 1990a; Golledge, Dougherty, and Bell 1993; Liao et al. 2017; and Irmischer and Clarke 2018. In survey learning, one's orientation in an environment can be perceived through north-up alignment (Shelton and Gabrieli 2002, 2004) or alignment with observable landmarks in the environment, such as landforms or buildings. The Pokémon GO player orients themself in the environment by referencing an in-game map, as seen in Figure 1. In the wayfinding (or route-based learning) process it is different. Pedestrian navigation in the real world involves movement, and spatial orientation is perceived through the position of objects in the environment, as well as local information received from different points of view. It is a sense of orientation that occurs while moving, which is what the player needs to do to successfully capture the Pokémons. Pokémon GO integrates both sources of spatial knowledge acquisition. As Kiefer, Giannopoulos, and Raubal (2014) claim, while wayfinding, self-location and spatial orientation are two crucial tasks. In survey learning or map-reading tasks, the perception of orientation is the north of a map or alignments with existing elements. While playing Pokémon GO, real-world streets and buildings are represented on a map, which indicates where the player is located. There is a compass to orient the map in the north direction, but the usual strategy is to position the map in the same direction in which the user walks. At the same time, in wayfinding, navigating, or route-based learning tasks, one's orientation can be perceived through the objects in the environment while in movement. This happens in the search of Pokémons, which are also associated with a geographical location. They are invisible until the player is at a certain distance from them, which is when they become visible and can be captured. Thus, the player needs to navigate in the environment, and go orienting themself with external references from the real world that appear on the map while moving.

METHOD

Background

In September 2016, forty-seven second-year engineering students of the subject of cartography of La Laguna University performed the Perspective-Taking Spatial Orientation Test.[1] Each academic year the research group for the development of spatial skills conducts the same spatial orientation test at the beginning of the course.

The overall mean score of these forty-seven students for the Perspective Taking Spatial Orientation Test (40.26 degrees) was better than in previous courses, which were in the margin between a minimum of 44.55 degrees (Carbonell 2017) and a maximum of 46.93 degrees (Carbonell et al. 2015). It should be highlighted that the Perspective Taking/Spatial Orientation Test overall score is the deviation between the participant's answer and the correct one; so, the lower the score obtained, the greater the success. It seems that something was affecting the spatial orientation skill values of students at the beginning of the 2016–2017 academic year. Noticing the difference in spatial-orientation ability in comparison to previous years, we hypothesized that the recent appearance of Pokémon GO might be responsible for this change. Therefore, we used the available collected data to assess the possible impact of Pokémon GO on the students'' spatial orientation skill. While it was not a controlled experiment, we believe initial results will inspire future controlled research on the likely impact of this game.

Out of forty-seven participants, fifteen played Pokémon GO; to quantify dedication to the game, those who had played Pokémon GO were asked the number of kilometers they had traveled (the Pokémon GO app measures the number of kilometers traveled while playing). The average value of the kilometers traveled by the students (Pokémon GO players) was sixty-six. Human beings, on average, walk at a pace of 6 km/hour; therefore, with an estimation of 10 km, the participants spent an average of 660 minutes playing the game (approximately eleven hours).

This duration exceeds that of other workshops related to the development of spatial orientation, which lasted either three hours (Carbonell and Bermejo 2017), four hours (Carbonell 2017), or up to eight hours (Carbonell et al. 2012; Carbonell et al. 2015). Consequently, time spent playing Pokémon GO could have factored into the improvement of the spatial orientation skill.

Data

The working hypothesis to analyze the effect of Pokémon GO on the spatial orientation skill was that students who played with Pokémon GO will exhibit higher spatial orientation skill than those who did not play. The thirty Pokémon GO nonplayers got similar Perspective Taking/Spatial Orientation Test mean scores (47.21 degrees, 28.43 standard deviation) to the previous years, while the fifteen Pokémon GO players got better scores (25.44 degrees, 16.97 standard deviation).

An independent *t*-test showed that those students who played Pokémon GO got a significantly better value (25.44 degrees) in the Perspective Taking/Spatial Orientation Test than that obtained by those who did not play (47.21 degrees) ($t(42.14) = 3.265$; $p = 0.002$). The difference was 21.77 degrees and the null hypothesis was rejected and stated that students who played Pokémon GO got better results for the spatial orientation skill than those who did not play.

In order to identify other activities that may influence spatial orientation, participants in the most recent study completed a survey determining their participation in orientation races and frequency of use of Google Maps, Geoportals, GPS navigators, and Google Street View. Research shows that these activities develop the spatial orientation skill (Carbonell et al. 2011, 2012, 2015; Carbonell 2017). They were also asked if they had played the game that gave rise to Pokémon GO: Ingress. The first (Orientation races) and last activity (Ingress) only had two possible responses (0–1): never, sometimes. The other activities could be responded between zero and four (never, between one and five times, between six and ten times, between eleven and twenty times, more than twenty times) (Table 1).

Thus, the *other activities* variable was created, which combines the frequency of use of these other activities. In this way, the variable has a possible range between one and eighteen. The descriptive statistics for this variable for Pokémon players/nonplayers were: Pokémon GO nonplayers N = 32, min = 2, max = 11, mean 5.244, 2.647 standard deviation and Pokémon GO players N = 15, min = 1, max = 13, mean 5.533, 3.563 standard deviation.

Table 1. Descriptive statistics (other activities related to spatial orientation).

Activity	N	Min	Max	Mean (s.d.*)
Orientation Races	47	0	1	0.13 (0.337)
Use of Google Maps		1	4	2.49 (1.214)
Use of Geoportals		0	4	0.68 (0.958)
Use of GPS-Navigator		0	4	0.54 (1.048)
Use of Google Street View		0	4	1.55 (1.348)
Playing Ingress		0	1	0.02 (0.146)

*s.d.= standard deviation

The performed t-test did not show a significant difference between players and nonplayers in *other activities* ($t(45) = -0.205$; $p = 0.839$). Furthermore, a one-way ANCOVA was carried out, including the *other activities* as covariate. The effect of the covariate was not significant ($F(1.46) = 0.177$; $p = 0.676$; $\eta^2 = 0.070$), so we can conclude that the *other activities* had no influence on the significant effect of the group (Pokémon player/nonplayer) in the scores of the Perspective Taking/Spatial Orientation Test ($F(1.46) = 7.273$; $p = 0.01$; $\eta^2 = 0.142$).

In order to study the effect of gender an ANOVA (2×2) was carried out. The only significance was obtained for the effect of having played Pokémon GO or not ($F_{1.46} = 7.831$; $p = 0.008$, $\eta^2 = 0.154$). There were no significant differences between men and women in either group (*p*-level > 0.05), neither was the interaction significant. Table 2 shows the results by gender.

Table 2. Perspective Taking/Spatial Orientation Test. Average values by gender.

Group	Mean Male Score N = 19 (s.d.*)	Mean Female Score N = 13 (s.d.*)
Pokémon GO nonplayers N = 32	N = 19 42.10 (30.71)	N = 13 54.67 (23.91)
Pokémon GO players N = 15	N = 9 24.56 (21.38)	N = 6 26.76 (8.43)

*s.d.= standard deviation

To contextualize this research, an ANOVA was carried out with the results from the present research and the results of three workshops specifically designed for the improvement of the spatial orientation skill. In the first workshop (SDI workshop), the sample consisted of 248 students. The experiment was conducted over four academic years (2009–2010, 2010–2011, 2011–2012, and 2012–2013). The technology employed to develop the spatial orientation skill was a geoportal: the Spatial Data Infrastructure (SDI-Workshop). In the instruction of this workshop exercises were carried out related to spatial orientation in the SDI Geoportal (Carbonell et al. 2015). In the second workshop, a so-called spatial-thinking workshop, a geographic information science (GISc) resource was used with 158 students of the subject of cartography, during the 2010–2011, 2011–2012, 2012–2013, and 2013–2014 academic years. In this case, students performed activities related to spatial-thinking acquisition: survey learning and route-based learning (Carbonell 2017). The third workshop was carried out with augmented reality (AR), with sixty-three students of the subject of cartography during the 2014–2015 academic year. Students determined locations from landforms using their spatial orientation skill to make a 2D/3D interpretation through visualizing the appearance of scenes from different vantage points (Carbonell and Bermejo 2017).

The research group for the development of spatial skills of La Laguna University conducted these workshops. The participants were second-year engineering students of the subject of cartography of La Laguna University, like those who participated in the present study. The research group assessed students' skill level using the Perspective Taking-Spatial Orientation test. In all cases, the students took the test before the workshops (pretest) at the beginning of the academic year and at the end of the workshops (post-test). As the present study evolved from an unexpected anomaly in student performance, the sample was divided into two independent groups: players and nonplayers. Due to this, and in order to be able to contextualize this sample with the previous data, the prepost factor of those data was treated as an intergroup factor: *with* or *without* activity. In this way, all premeasures were treated as *without activity* and all postmeasures as *with activity* (Table 3).

The performed ANOVA gives a significant effect for the activities ($F_{7,985} = 30.376$; $p = 0.000$; $\eta^2 = 0.179$). Post hoc comparisons (Sidak) show significant differences comparing each level *without activity* with all levels *with activity* (p-level < 0.05). On the other hand, there are no differences between the levels *without activity* or between the levels *with activity* (p-level > 0.05). Figure 2 shows the scores of the Perspective Taking/Spatial Orientation Test for *with* or *without activity* in each workshop.

Finally, an additional survey with dichotomous answers (yes/no) was conducted in order to know how the

Table 3. Average values for ANOVA in the Perspective Taking/Spatial Orientation Test.

		Perspective Taking/Spatial Orientation Test	
Workshop	**N**	**Without activity (Pretest) (s.d.*)**	**With activity (Post-test) (s.d.*)**
SDI-Workshop	248	46.93	27.72
		(25.29)	(18.91)
Spatial Thinking Workshop	158	44.55	25.49
		(21.74)	(16.73)
Augmented Reality Workshop	63	46.01	25.87
		(13.65)	(14.73)
Average Workshop Score	*469*	*46.00*	*26.72*
		(23.42)	*(17.68)*
Pokémon GO	32 and 15	**Nonplayer**	**Player**
		47.21	25.44
		28.43	16.97

*s.d. = standard deviation)

students found using Pokémon GO, with questions related to spatial orientation (Table 4).

Conclusions and Future Research Questions

Pokémon GO has been identified by the scientific community as an application that can benefit users by

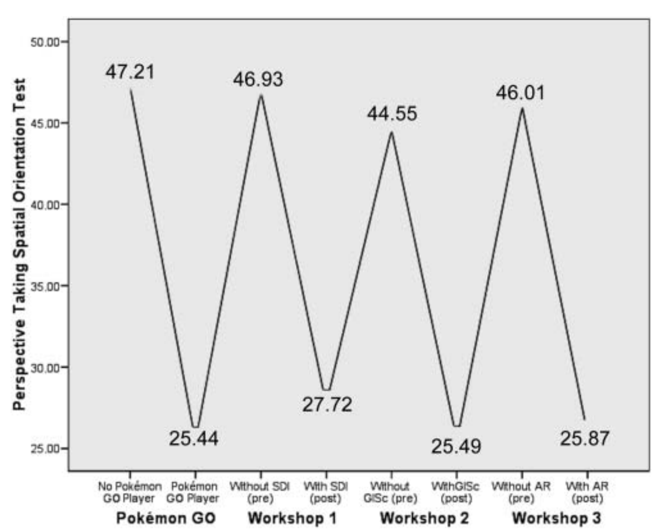

Figure 2. Scores of the Perspective Taking/Spatial Orientation Test for with or without activity in each workshop.

Table 4. Results of the survey on the use of Pokémon GO.

Question	Yes	No
When you play with Pokémon GO, do you hit the compass on the top right to mark the north?	45.5%	54.5%
When you play with Pokémon GO, the streets have no name. Does this imply any difficulty in orienting you?	20%	80%
Do you think that playing Pokémon-GO can develop your ability to orient yourself in space?	75%	25%

promoting physical activity (Butcher 2016; McCartney 2016). There has also been research on its influences at the cognitive level (Ruiz-Ariza et al. 2018; Zachary 2016; Khanade and Sasangohar 2017), though its impact on spatial orientation ability has not yet been studied. Past research has shown that spatial skills can be improved through training activities (Newcombe and Stieff 2012; Carbonell et al. 2015), and Pokémon GO may serve as one such experience that can specifically benefit the spatial orientation ability of its users.

It cannot be stated, based on the data collection presented in this research, that Pokémon GO increases the spatial orientation skill of the students, because it is not a controlled experiment. Even so, we consider the results relevant within their limitations, and believe they offer a starting point for future work.

In the present research, students who played Pokémon GO performed better on the spatial orientation skill than those who did not play. The difference between Pokémon GO players and Pokémon GO nonplayers (21.77 degrees) is statistically significant, despite *other activities*. It is possible that the results could be explained through self-selection bias. Indeed, there may even be a hint of this bias in action in the collected data, because the average nonplayer score (47.21 degrees) was somewhat higher (i.e., they had worse spatial orientation abilities) than the average pretest scores (46.00 degrees) from those students participating in the other workshops.

No gender differences were found in the acquisition of spatial orientation, which coincides with other research on gender and spatial orientation (Beaumont et al. 1984; Montello and Pick 1993; Montello et al. 1999). But there is also research that claims the opposite (Sadalla and Montello 1989; Malinowski and Gillespie 2001; Carbonell et al. 2011, 2012).

Future Research Questions

The very nature of the research carried out, indeed, does not offer results with which it can be confirmed that spatial orientation increases by playing Pokémon GO, although they do suppose a starting point for future controlled research. In this future work, a measurement of the spatial orientation skill could be made before (*pre*test) and after (*post*-test) a controlled Pokémon GO activity with students who had never played Pokémon GO.

Also, in this future experiment, more variables could be considered, because other factors may influence Pokémon GO players' higher score. In this sense, it could be studied why Pokémon GO attracts certain students of cartography and not others. It could be that greater spatial orientation skills influenced the likelihood of playing Pokémon GO and therefore the influence of the game on spatial orientation ability is actually not as high as that presented in this research.

In relation to gender, in the investigations carried out previously we have observed differing conclusions. It depends on factors including different degrees of familiarity that both males and females may have with operating the orientation material provided (Liu et al. 2011). Thus, for future work we propose research on the spatial orientation skill to analyze gender differences in wayfinding and map reading tasks separately.

Having this in mind, playing Pokémon GO, therefore, could be considered as a tool for the improvement of the spatial orientation skill in university students after corroborating the improvement in a controlled experiment. A good level of spatial orientation makes it easier for students to understand the three-dimensional space represented in maps and georeferenced information. Furthermore, in the survey conducted, 75 percent of Pokémon GO players felt that interaction with the game developed their ability to orient themselves in space. Thus, playing Pokémon GO could promote learning of the subjects related to topographic and cartographic representation.

Spatial skills improvement derived from playing videogames is comparable to the effects of formal teaching courses (Uttal et al. 2013). According to this affirmation, playing Pokémon GO could develop students' spatial orientation ability in the same way as formal teaching courses specifically designed for the development of spatial orientation. Formal teaching courses (workshops) designed for spatial orientation enhance the need for planning and resources that are not needed with the Pokémon GO application, and the results for spatial orientation skill acquisition are similar.

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Note

1. This test (with instructions) is available at the Spatial Intelligence and Learning Center (*http://www.silccenter.org/index.php/resources/testsainstruments*).

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