Validity and Reliability of Eye-Tracking as a Measure of Impasse

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Abstract

Creativity in human cognition will be the focus of the current study. More specifically, the theory of insight problem solving will be investigated. Insight includes a moment of high amounts of suddenness, high amounts of confidence, and low amounts of effort involved in finding the solution. In the process of insight problem solving, a person will most likely reach a period known as impasse, the subjective feeling of not knowing what to do or simply being stuck. This study aims to identify the validity and reliability of eye tracking as a measure of insight by comparing the method against Think Aloud Protocol and Aha! Ratings, which is a self-reported measure. The study predicts eye tracking will be more reliable compared to the current methods of Think Aloud and Aha! Ratings since it can decrease bias in interrater reliability and will have predictably less interference in reliability since it does not require the participant to have a full understanding of the concept and rate themselves subjectively.

Validity and Reliability of Eye-Tracking as a Measure of Impasse

Creativity in cognitive psychology can be defined as the study of creation of new ideas; for instance, solving a math problem or trivia answer. In the study of creativity in cognition, there are two theorized ways to go about a problem: incrementally and insight.

Researchers have proposed that in insight problem solving, a person's prior knowledge is of little use, and they cannot solve a problem by a series of logical steps. They will most likely reach a period of *impasse*. A period of impasse can be characterized as the moment when a person considers themselves to be stuck and the solution seems unattainable. After the period of impasse, they must restructure the problem space, which simply means they must change the way they view the problem and how they are currently attempting to solve it. If a person restructures the problem correctly, they will then be able to find a solution, which may include an Aha! Moment. An Aha! Moment is one in which a person feels high levels of suddenness, high levels of confidence in their answer, and low levels of effort in attaining the solution.

Incremental or non-insight problem solving, also called "analytical problem solving" is the theory that a problem is solved by a series of step processes to achieve a solution (Chuderski & Jastrzebski, 2018). These kinds of problems are most easily seen in algebra where prior knowledge, strategies, and algorithms further help a person work through a problem at hand, systematically finding a solution.

Alongside incremental problem solving is insightful problem solving, defined as "suddenness … and the subjective Aha! Experience" which can be related to the epiphany feeling when solving trivia or completing a Rubik's cube (Danek, Williams, & Wiley, 2018). Researchers have found evidence to suggest there is a difference between insight and incremental problem solving.

Evidence of the difference between insight and non-insight problem solving has been distinguished since Bergson's discovery of the "intuitive mode" in 1902. Metcalfe and Wiebe (1987) supported theorized differences by showing insight as "characterized by a sudden, unforeseen flash of illumination," which we now call the Aha! Moment. Metcalfe found non-insightful problems to have an incremental progression towards an answer to predict solutions, while insightful answers were unpredictable and seem to reach a solution spontaneously (Metcalfe & Wiebe, 1987).

In the theory of insight, representational change theory views impasse as a product of an incorrect initial idea of the problem, and must have the initial idea changed in order to find the solution (Knoblich, Ohlsson, & Raney, 2001). In this theory, impasse occurs when the person has an incorrect idea of the problem, and insight occurs when the "initial representation has changed" (Knoblich, Ohlsson, & Raney, 2001). Others argue that representational change theory is not unique to insight. Thevenot and Oakhill (2008) argue the process in constraint relaxation and chunk decomposition are the same as the process described in representational change.

In insight problem solving, there are two theorized approaches to the methods impasse is overcome: automatic or controlled. Automatic processes are thought to be the Aha! Moment after impasse because of spreading activation through the brain. Ash and Wiley (2006) support automatic processing by isolating problems to "few moves" possible to "investigate the nature of restructuring." Controlled processes are thought to have "the same conscious mechanisms" as non-insight problems (Chein & Weisberg, 2013). Ball and Stevens (2009) advocated for the controlled process, also called business as usual view, by isolating "articulatory suppression" against thinking aloud, finding "implicit spreading activation" was hindered by the inability to think aloud.

Identifying and studying the experience of insight in cognitive psychology has proven to be difficult for researchers (Davidson, 2003). The interaction between the problem and a person's experience is the key to answering questions on insightful problem solving, but can be difficult to study outside of the mind of the solver.

Since the way a person goes about a problem uses either incremental or insight problem solving. Researchers first need to identify if a solution is insightful or non-insightful to be able to study restructuring. To identify insight, researchers have come up with three main approaches: analyzing Aha! Moments in terms of self-ratings to compare scores or Aha! Ratings (Schooler, Ohlsson, & Brooks, 1993); using a Think Aloud Protocol (Chein, Weisberg, 2013) in which people voice their thoughts as they solve a given problem; and examining eye fixation patterns through an eye-tracking system (Huang, 2017).

In order to study impasse and restructuring, the common method is Think Aloud Protocol (also known as Verbal Protocol) coupled with Aha! Ratings. Chein and Weisburg (2013) used Think Aloud Protocol studied how voicing problems affects insight problem solving, and found no evidence to suggest an impact. Since they were only interested in the effect of voicing or not voicing problems, videos were not recorded or saved for analysis (Chein and Weisburg, 2013). Cranford and Moss (2012) also used Think Aloud Protocol to examine verbal overshadowing. Verbal overshadowing is the theory that articulating problems verbally affect insight problem solving, which was supported in Cranford and Moss (2012). Think Aloud Protocol can accompany low reliability ratings and wavering validity in terms of its use as a measure of impasse (Ash, Jee, & Wiley, 2012).

Studying impasse through Aha! Ratings has low validity due to the reliance on participants to be the measure and variability in the definition of an Aha! Experience (Shurkova, 2019). This

causes problems because most parts of the measure are relative, each participant may judge themselves differently in terms of what they believe an impasse experience contains or what comes as a sudden solution. Bowden and Jung-Beeman (2003) used Aha! Ratings and commented the method "is flawed, … and possibly inconsistent across participants." Aha! Ratings result in low validity because it emphasizes subjective suddenness in a person's problem solving in both methods (Lee, 2015). In self-reporting, a person is subjective in their own answers. In Think Aloud Protocol, a person's impasse is too subjective even when following a specific rubric of body language to code for impasse (Shurkova, 2019).

Yeh, Tsai, Hsu and Lin (2014) found participants who solved solutions with insight had "longer gaze duration," and "more fixations and saccades to all objects". Eye-tracking may be a viable option for studying impasse since it eliminates the subjectivity of ratings among raters and self-reporting participants. Eye-tracking can provide more quantified data with predictably less interference of inter-rater reliability difficulties, subjective questions that lead to variations in responses about impasse, and debatable start and end times of impasse. The analysis of eye-tracking could possibly lead to an equation for impasse that could be used across more than just this study or this lab.

This study aims to test the validity of eye-tracking as a method for identifying insight against verbal protocols and Aha! Ratings. This study intends to replicate previous findings that indicated impasse was unreliable (Shurkova, 2015). The study will also follow up on previous research that has come to a "division in the literature" with an overall goal to fully evaluate the reliability of impasse through Think Aloud Protocol (Lee, 2015). Previous research has found results on eye-tracking data by using fixation times as evidence of impasse (Yeh, Tsai, Hsu, & Lin,

2014). This study will test whether eye-tracking, self-reported ratings, or verbal protocols best correlate to impasse and best represents the most consistent results.

Methods

A target number of participants includes 200 students through the Old Dominion University Psychology Department Research Database, SONA. The database is open to anyone enrolled as Old Dominion University. Many students in psychology courses are required to obtain credits. The study will be posted in SONA where students can choose from a variety of experiments and receive a credit in the database. This credit can be used for extra credit or course requirements, with professor discretion on how the credits are applied. Selection is open to anyone in the SONA system

To evaluate Self-Reported Impasse, Think Aloud Protocol, and Eye-tracking, this study will be following a mix of all protocols. The researchers will be using the following insight problems in a randomized order (see Appendix A, figure 1): Knoblich's matchstick problems (Knoblich, Ohisson, Haider, Rhenius, 1999); Schooler, Ohlsson and Brook's triangle problem (1993); Katona Squares (Ash & Wiley, 2006); Ormerod, MacGregor and Chronicle's Hexagonal Coin Problem (2002). When looking at these problems, people will be tested with Aha! Ratings in each of the three techniques (Eye-tracking, Think Aloud, and self-reported Aha! Ratings).

Immediately after each insight problem, participants will self-report Aha! Ratings of impasse. Each participant will answer three questions after every solution provided. The questions will be asked on a 6-point scale determining how confident the person is in their answer, how much effort they feel was required for the answer, and how suddenly the answer came to them (see Appendix A). The answers rated high in confidence and suddenness as well as low in effort will be considered insight problem solving.

Think Aloud Protocol asks participants to voice all thoughts while they work through the presented problem. As they voice their mental process, the participant will be video recorded. After being recorded a researcher will turn impasse into binary following a specified coding rubric. The rubric includes behavior the participant displays, such as a period of silence, body language including fidgeting or exasperation, or repetition of the given question mindlessly, then the person will be considered to have experienced an impasse in their problem solving (see Appendix B).

Eye-tracking will measure Aha! Ratings by using the departmental software, E-Prime 3. E-Prime 3 is the most common programming platform for eye-tracking in experimental psychology. As the participant completes problems, the eye-tracking program will record fixation, duration and the regions of interest on the screen. Participants will not need to perform any tasks during the experiment other than the original calibration of the system on their eyes.

This eye-tracking software will measure fixations on the screen in terms of specified sections. Each section will be examined when looking for possible trends between impasse and the solution portion of the experiment. In order to use the eye-tracker, a researcher must program the entire experiment in E-Prime 3 and turn the data recorded from the eye-tracker into usable data, which can then be put into statistical programming software that will be used (in SPSS).

Proposed Analysis

Impasse will be determined based on a peak in fixation time on specified regions of interest in eye tracking; high confidence, low effort, and high suddenness in Aha! Ratings; and the coded number one in Think Aloud Protocol based on the impasse coding sheet (see Appendix B). Chi square tests of independence will be conducted between each of the three protocols; Aha! Ratings and eye tracking, eye tracking and Think Aloud, and Think Aloud and Aha! Ratings. Correlations

between each protocol and impasse will be examined to identify which protocol best correlates with the correct identification of insight problem solving.

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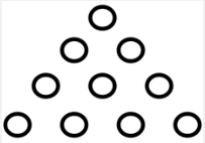
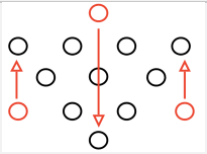
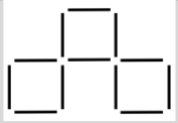
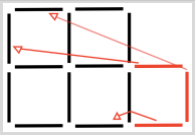
Appendix A

Figure 1.

Insight Problem	Instructions for Problem and Solution
Matchstick Arithmetic	Move one matchstick to correct the equation
	
Triangle Problem	Move 3 dots to change the direction of the triangle
	
Katona Squares	Move 3 lines to make 5 squares
	
Hexagonal Coin Problem	There are 8 coins in this picture. Move 2 coins so that each coin touches exactly 3 other coins.
	
Glasses	The picture below is of 6 glasses with liquid and 13 coasters. Describe how you could make it so no 2 glasses containing liquid are next to each other and no 2 empty glasses are next to each other, while keeping 3 of the 6 glasses full. To do this, you are only allowed to move 1 glass and all glasses must end up on a coaster.

Appendix B

Impasse Coding Sheet:

Operational Definition of **Impasse:**

The cessation of overt problem-solving behavior which is accompanied by a subjective feeling of not knowing what to do.

Looking for:

- periods of silence (especially after reminders)
- repetition of the instructions
- verbal indications of impasse (e.g., "I don't know what to do", "This is impossible")
- physical stillness (e.g., stop writing)
- still or frustrated body language (e.g., sitting back in chair, throwing hands up in exasperation)