Inductive Reasoning Developmental Test – Second Revision (TDRI-SR): Content Validity

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Abstract: The Inductive Reasoning Developmental Test [Teste de Desenvolvimento do Raciocínio Indutivo – TDRI] measures seven stages of this ability. Although the TDRI presents evidence of internal and external validity, its abstract stages show some problems that produce a false-positive and false-negative classification of people on these stages. A new version of TDRI was developed (TDRI-SR) and the issues found in the current version of TDRI were also described. Six judges were asked to evaluate the TDRI-SR and the described issues. All judges assent with the described issues. The first two judges identified some issues with the TDRI-SR and a new version was developed. The other four judges evaluated this version and did not find any problem. The TDRI-SR allows better identification of the abstract stages of inductive reasoning and presents more robust evidence of content validity than its previous version.

KEYWORDS: stages of development; reasoning; intelligence; validity.

1. INTRODUCTION

Several variables are recognized as relevant predictors of academic achievement, such as student approaches to learning (Gomes, 2010a, 2011a; Gomes, et al., 2011; Gomes & Golino, 2012b; Gomes, 2013), metacognition (Gomes & Golino, 2014; Gomes, et al., 2014), students' beliefs about the teaching-learning processes (Alves, et al. 2012; Gomes & Borges, 2008a), motivation for learning (Gomes & Gjikuria, 2018), academic self-reference (Costa, et al., 2017) and learning styles (Gomes, Marques, et al., 2014; Gomes & Marques, 2016). All of these predictors assume, even implicitly, that there is an active interaction between the person and the objects of knowledge (Cardoso, et al., 2019; Gomes, Golino, et al., 2014; Pereira, et al., 2019), being in consonance with the psychoeducational constructivist theories (Golino, et al., 2014; Gomes, 2007; Gomes & Borges, 2009a; Gomes, 2010a; Pires & Gomes, 2018) and neuropsychology (Dias et al., 2015; Reppold et al., 2015). However, intelligence has a prominent role in the prediction of academic achievement, especially in primary and secondary education (Alves, et al., 2016, 2017, 2018; Gomes & Borges, 2007, 2008b; Muniz, et al., 2016; Valentini et al., 2015).

The Inductive Reasoning Developmental Test [*Teste de Desenvolvimento do Raciocínio Indutivo - TDRI*] was developed by combining two approaches in the study of intelligence, namely developmental psychology and psychometrics. The TDRI is guided both by the Cattell-Horn-Carroll (CHC) model of intelligence from psychometrics and by the hierarchical complexity theory, a neo-Piagetian developmental model (Gomes et al., 2014b). The instrument measures reasoning, an ability located at the stratum I of the CHC model, which is associated with fluid intelligence (Gf) at the stratum II of the model. The TDRI test measures seven developmental stages of reasoning, being guided by the mathematical model of hierarchical complexity (Golino, et al., 2014), which is an innovation in the assessment of intelligence.

The TDRI test has its origin in the efforts of the Laboratory for Cognitive Architecture Mapping [*Laboratório de Investigação da Arquitetura Cognitiva - LAICO*] at the Federal University of Minas Gerais to develop a new intelligence battery, the *Battery of Higher-Order Cognitive Factors* [Bateria de Fatores Cognitivos de Alta-Ordem - BAFACALO] (Golino & Gomes, 2014b). The BAFACALO battery was a pioneer in the use of the CHC model in Brazil,

using 18 intelligence tests measuring general intelligence (g factor) and six broad abilities of the CHC model. This battery, and its constituent tests, have presented evidence of internal validity (Gomes, 2010b; Gomes, 2011b; Gomes, 2012; Gomes & Borges, 2009a, 2009b; Gomes, de Araújo, et al., 2014; Gomes & Golino, 2015) and external validity (Alves et al., 2012; Gomes, 2010c; Gomes & Golino, 2012a, 2012b; Gomes et al., 2014). Particularly, the TDRI test is an extension of the *Inductive Test* from BAFACALO, to measure distinct levels of reasoning capacity (developmental stages). The inductive reasoning test from BAFACALO has 15 items, which are composed of five groups of four letters. Among the groups of letters, one does not follow the same rule as the other groups of letters. To correctly answer the items, one needs to discover which group of letters follows a different rule. The TDRI items have a similar design: items are formed by groups of letters with a specific rule, and only one group of letters present a different rule. The difference is that the TDRI items were developed using the mathematical model of hierarchical complexity as a reference, organizing the items according to the level of information needed to be manipulated in order to correctly answer an item. The test measures seven developmental stages, with increasing complexity from the first to the seventh stage (Golino et al. 2014). Each stage has eight items with the same level of complexity, verified using item response theory (Golino & Gomes, 2019). The first stage, named *single representations*, involves the capacity of form single units of representations in the mind from actions and perceptions acquired in the interactions with the world. This stage is similar to the most basic stage of representation of the Piagetian theory (Commons, 2008). The second stage is named *representational mapping*. In this stage, the person is capable of connecting two single units of representations in a map that integrates these units, forming a new and more developed stage of thinking. The third is the representational system stage. In this stage, the person is capable of connecting two maps of representations. The fourth is known as the single abstraction stage. This stage is similar to the most basic stage of abstraction of the Piagetian theory (Golino & Gomes, 2019). At this level, the person is capable of integrating two systems of representations, which produces a qualitative change of thinking. The fifth is the abstract mapping stage, which integrates two single units of abstraction. The sixth is the abstract system stage, which integrates two maps of abstraction. The seventh and last is the metasystematic stage, which integrates two abstract systems, producing another qualitative change of thinking (Golino et al. 2014; Golino & Gomes, 2019).

The process of developing and validating test is a recursive and complex one, and with the TDRI was no different. The first version of TDRI had forty-eight items, with some limitations identified using both the Rasch model and confirmatory factor analysis (Golino & Gomes, 2019). To identify the stages of development, each group of items of the test (each identifying a specific stage) must present similar levels of difficulty. Furthermore, it is mandatory the presence of a “gap”, that is, a relevant distance between groups of items representing adjacent stages, in terms of difficulty. These “gaps” are important and central evidence of qualitative changes that represent "jumps" in the development of reasoning, from stage to stage (Golino & Gomes, 2019).

The analysis of the first version of the TDRI test showed that some items or groups of items must be eliminated or changed, since they were incapable of producing the necessary gaps for measuring separate stages of reasoning (Golino et al., 2014). Therefore, a revised version was

produced. This second version has 56 items and is the current form of the test, published by Hogrefe in Brazil. The TDRI test (Second Version) presented evidences of structural and external validity (Golino et al., 2014; Golino & Gomes, 2014a; Golino, Gomes, & Andrade, 2014; Gomes, et al. 2013; Gomes, Golino, et al., 2014).

Despite the advances achieved by the revised version of TDRI test, it still has relevant issues that must be addressed. These issues were identified by a rigorous analysis of the authors and by qualitative feedbacks from some respondents. Through this process, it was possible to identify issues in the more advanced stages: the single abstraction stage, the abstract mapping stage, the abstract system stage, and the metasystematic stage. The analysis of the authors and the qualitative feedback show the need to modify the items from the more advanced stages of the TDRI, since it is possible to answer the items using strategies that are not representative of the stage of reasoning measured in each stage (a problem of content validity).

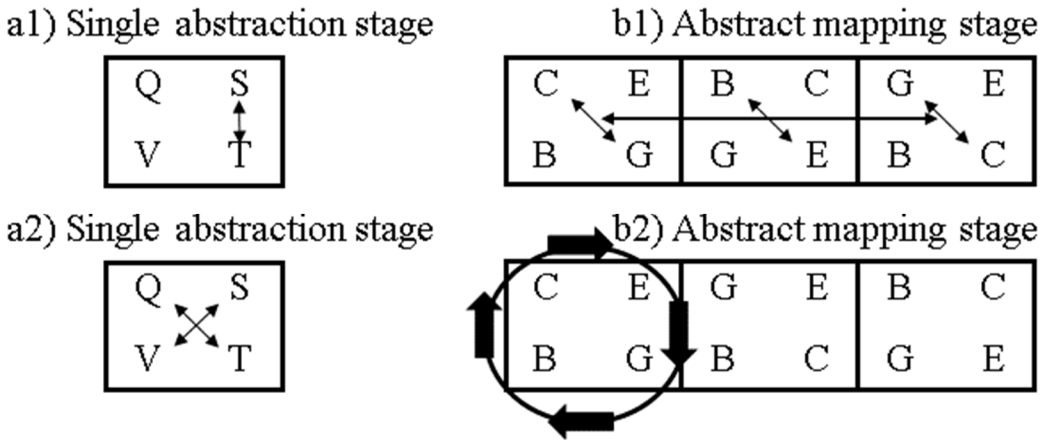
There are three main issues with the single abstraction stage items. Adequate items for measuring the single abstraction stage must require the respondent to integrate two representational systems. In the case of the current version of the TDRI, a respondent can complete the items of this stage by using a strategy that only maps single representations, not requiring them to operate at an abstract level. As shown in Figure 1 (a1), the respondent can answer an item by articulating the letters disposed on the right side of each box. In this case, this articulation makes a representational mapping. This is relevant since we expect that the respondents only correctly answer the items of this stage cognitively, operating through the abstraction of single units. If a person can correctly answer the items of the single abstraction stage using maps of representations, then the test will classify erroneously certain individuals as operating in the abstract level, when, actually, they operate through lower stages of reasoning. This condition generates false-positive classifications. The second problem concerns the rule of this stage, showed in the current version of the TDRI manual (Golino & Gomes, 2019). This rule involves two different strategies, producing a relative degree of arbitrariness that should not happen, since the driver of the scores must be the logical reasoning. This condition needs to be changed, and the rule used needs to be straighter and clearer. This issue is not shown in Figure 1 in order to preserve the answer key of the test. The third issue is the existence of a valid rule, not identified in the TDRI manual (Golino & Gomes, 2019). As shown by Figure 1(a2), the items of this stage can be solved by relating both diagonals. However, this rule requires single abstraction units. Therefore, it is not problematic as the previously described issues because this rule does not produce false-positive classifications.

Adequate items for measuring the abstract mapping stage are tasks in which the person must integrate two (or more) single abstractions. The items of the current version of TDRI demand that the respondent makes this integration. However, these items can also be solved by a strategy that requires single abstraction processes, also potentially generating false-positive classifications. As featured in Figure 1 (b1), the respondent can correctly answer an item only by relating the diagonals from the top left letter to the bottom right letter inside each one of the three boxes and connecting these patterns. The identification of only one diagonal is a representational system, while the connection of this diagonal to three boxes makes a singular abstraction. If both diagonals inside each box and between the boxes must be articulated by the respondent in order to correctly

answer the item, then the stage involved in this task would be correct, that is, an abstraction mapping. However, as mentioned before, only one diagonal inside each box should be identified for a response to be considered correct. There is also an issue at this stage which the respondent can erroneously observe and integrate only the left boxes. This is a minor issue, since this strategy brings the respondent to fail the item. Figure 1 (b2) shows this minor issue, in which the respondent finds a pattern associated with the clockwise direction, in which the letters are arranged only on the left box. The respondent ignores the boxes in the middle and on the right.

At the abstract system stage, there is an issue with the rule connecting the letters that inconsistent. A consistent rule must be coherent. For example, if the rule is the existence of a pattern in the horizontals of the letters, then this pattern must occur at the superior horizontal and the inferior horizontal. When the rule is not consistent, we name it a pseudo-rule, and that's the issue in this stage. Again, this issue is not shown in Figure 1 in order to preserve the answer key. Similar to the abstract system stage, the metasystematic stage items are problematic because the rule connecting the letters is a pseudo-rule.

Figure 1
TDRI issues.



Note. The items shown in the figure are not the same of TDRI.

Considering the problems pointed above, the first four authors of this paper have created the TDRI-SR [*Teste de Desenvolvimento do Raciocínio Indutivo* (Second Revision)], changing all items from the single abstractions stage, the abstract mapping stage, the abstract system stage, and the metasystematic stage. The qualitative feedback mentioned earlier also pointed to the length of the test. Many respondents mentioned that the current version of TDRI is interesting but very hard, with many items (56), and that a test with fewer items would be more comfortable for them. Therefore, we decided to reduce the number of items from 56 to 28, with seven groups of four items, each measuring one of the seven stages of reasoning of the TDRI test. We followed a rigorous evaluation of possible alternative answers to each item when we developed the new items. We want to ensure that the respondent does not answer correctly by using strategies of lower stages, nor that the respondent is induced to answer incorrectly based on a pattern that does not

concern the rule of that stage. Furthermore, we believe that we have solved all the problems of the current version of the TDRI, and the test is much improved. In the current paper, we describe the content validity of the TDRI-SR.

2. METHOD

To make a judicious and rigorous examination of both the current and revised versions of TDRI, six judges were invited to evaluate all the steps in the development of the TDRI-SR. This evaluation was made with the goal of verifying whether the second revision and its new items presented some non-identified errors by the authors of the second revision. The judges inspected if the new items showed patterns in the vowels, patterns in the lines of the sequences of letters as well in the columns and in the diagonals of the sequences, as well as many other patterns (see Table 1 and Table 2).

2.1. Participants

The judges were invited based on their educational and professional background. All judges are professionals working with activities requiring reasoning and in which analyzing steps of a task is essential. All the judges are male. Two judges are 22 years old and reported not being familiar with reasoning tests, however, both of them studied Mechanical Engineering at a renowned Brazilian university of technological sciences. A judge is 29 years old and reported being familiar with reasoning tests, he studied at a renowned federal university in Brazil and works as a programmer. The two judges, which are 31 and 30 years old, are PhD students from the same Brazilian federal university and reported being familiar with reasoning tests, and both have experience with psychometrics. The last judge is a 24 years old master's student at the same university. He also reported being familiar with reasoning tests and working on projects related to psychometrics and programming.

It is important to have judges with and without experience in test construction and psychometrics in this revision process, since the goal is to obtain qualitative feedbacks, check for possible errors, and increase the content validity of the instrument. This is usually done by recruiting content-expert judges, but since the TDRI is a logical reasoning test involving groups of letters that are combined given specific rules, there is no need to recruit content experts, since this was done previously in the development of the Inductive Reasoning test of the BAFACALO battery.

2.2. Review process

The judges evaluated the TDRI-SR as well the current version of TDRI, following a protocol that made the evaluation a standardized process. Following this protocol, instead of showing the 56 items of the current version of TDRI and the 28 items of TDRI-SR, the authors of the TDRI-SR presented only one item of the current TDRI and one item of the TDRI-SR from the singular abstractions stage, the abstract mapping stage, the abstract system stage, and the metasystematic stage. Just one item per stage was presented in the protocol due to the fact that all items in the same stage follow the same rule and have the same framework.

Firstly, the judges answered questions related to their sociodemographic characteristics and whether reasoning tests and their items were usual and familiar for them. Then, the authors presented the TDRI in terms of what ability the test measures, what is the goal of the test, how the items look like and also informed that the test assesses different levels (stages) of ability. Next, the authors stated that the current version of TDRI could have some problems with the rules of the four levels (stages), affecting their items. Concomitantly, the authors informed that the judges should evaluate whether the remarks of the authors about the items of the current TDRI, as well the new item of the TDRI-SR were correct. If not, the judges should justify what they do not agree with, answering in a specific space in the protocol. Then, the authors showed the judges how to evaluate one item of the current version and one item of the second revision of TDRI from the four stages mentioned above, using a specific check-list (see Table 1 and Table 2). If the judges considered that the remarks of the authors were correct, then they wrote an "OK" in the proper column of the singular abstractions item. Whenever one of the judges noticed any problem related to the current or revised version of TDRI, the judge presented his suggestions for changes to one of the authors of the test. Then, both the judge and the author carefully examined the suggestions. If they agreed that the suggested changes were consistent and necessary, they would create a new protocol to be analyzed by the judges. This new version was updated every time a problem was identified. Then, the next judge would examine the updated document and make his own evaluation. This process was repeated recursively until none of the judges identified any lasting problem. The process was carried out recursively so that any suggested changes to items would be judiciously evaluated to generate a final version of the document that would serve as a basis for robust modifications of the test. A total of six evaluations were performed, one per judge. Each agreement between each judge and the authors regarding the twelve categories of the checklist (Table 1 and Table 2) was counted as zero, and each disagreement was counted as one. In order to identify the total number of disagreements per judge, all were summed. This sum was divided by the total number of cells of the checklist (86 cells) to calculate the percentage of disagreements of the judge.

Table 1

Checklist of the categories one to six to be evaluated by the judges

Items	rule	vowel	line	column	diagonal	direction
Singular abstractions current item						
Singular abstractions second revision item						
Abstract mapping current item						
Abstract mapping second revision item						
Abstract system current item						
Abstract system second revision item						
Metasystematic stage current item						
Metasystematic stage second revision item						

Table 2
Checklist of the categories seven to twelve to be evaluated by the judges

Items	equal letters	distance and sum of letters	distance of lines and columns	sum of diagonals	W pattern	adequate item
Singular abstractions current item	—	—	—	—	—	
Singular abstractions second revision item	—	—	—	—	—	
Abstract mapping current item						
Abstract mapping second revision item						
Abstract system current item						
Abstract system second revision item						
Metasystematic stage current item						
Metasystematic stage second revision item						

3. RESULTS AND DISCUSSION

No judge disagreed with the remarks made by the authors concerning the problems of the current version of the TDRI. Since each judge did not know about the evaluation made by the other judges, the absence of disagreements indicates that the problems identified by the authors were pertinent. These problems affected the correct diagnosis of the respondent on higher stages of reasoning. As a result, the judges acknowledged that the current version of TDRI should be modified.

Concerning the TDRI-SR, the first judge had two disagreements, both of them related to the single abstraction stage, which corresponded to 2.3% of the 86 checklist's cells. The judge reported an issue related to the rule of this stage, hence also disagreeing with the adequacy of the item. The authors agreed with the judge and corrected the problem by changing the rule and the items of this stage.

The second judge received the updated protocol and had 6 disagreements, corresponding to 7.3% of the 86 checklist's cells. The authors agreed with the six problems identified by the judge and, they recognized that these issues should be fixed. The first author of the test together with this judge fixed those problems. Because his participation was substantial, this judge was invited to be a co-author of the TDRI-SR. The protocol was updated after the corrections were presented by the second judge and all the other judges reviewed this protocol. The subsequent judges did not find

any problem related to the TDRI-SR. Insofar, as each judge did not know about the previous judge's evaluations, the result strengthened the content validity of the TDRI-SR.

4. CONCLUSION

This study highlights the relevance of a rigorous content validity examination in test construction and validation. Previous studies that applied the current version of TDRI identified "gaps" that were recognized as evidence of qualitative changes in the development of reasoning, representing stages of inductive reasoning. These findings would suggest that the content validity of TDRI was guaranteed since the stages were differentiated. However, the present study shows that the current version of TDRI has some issues on its abstract stages, suggesting that the content validity of this version is not solid. Actually, the "gaps" founded can also be a consequence of the described pseudo-rules, then we cannot claim that the abstract stages were well identified. In order to judiciously evaluate the issues pointed in the introduction, a recursive judge evaluation was carried out. We believe that recursion on performance tests is desirable since they generally demand complex tasks and adds rigor to the examination process.

This study reports the development of the TDRI-SR through fixing the issues of the current version of TDRI, and using qualitative judgements from respondents to address the content validity of the test. Since TDRI-SR was judiciously evaluated, we believe that the next step is to apply it in a broad sample to investigate its structural validity. Besides that, the external validity of TDRI-SR should also be evaluated. The current version of TDRI had its convergent validity exanimated in two studies, each composed of a sample with less than 200 subjects, and both did not apply the items of single representation and the metasystematic stage (Golino & Gomes, 2019). It would be of great value for the external validity of TDRI-SR to expand the external validity studies beyond convergent validity. Future studies should include a diversified sample and also apply items of the first and the seventh stage so that the relationship between those stages and other variables can be investigated.

In the current study, the content validity issues of the TDRI were addressed, producing a better testing procedure with fewer false-positives and false-negatives, since the problems that produce those wrong classifications were fixed. The TDRI-SR is also shorter, having half the items of its current version. Since this test demands a significant cognitive processing load, the reduction in the number of items is a great deal, since having many items per stage may generate fatigue and decrease the performance of the respondents.

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