CERN IdeaSquare Journal of Experimental Innovation, 2023; 7(1): 4-11
DOI: https://doi.org/10.23726/cij.2023.1416

ORIGINAL ARTICLE

Why measuring individual innovativeness is so difficult: a critical review of standard methods and new ideas to measure innovativeness

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ABSTRACT

Innovative people are desperately wanted in nowadays world, wherefore tools to measure individual innovativeness are needed. This work reviews the commonly used metrics to gauge innovativeness, such as the Individual Innovativeness Scale (IIS). Hereby, it demonstrates via a survey that often a simple self-evaluation question contains the same information as conventional psychological surveys. As an alternative, another survey investigates whether bibliographical information can help in predicting innovativeness. Finally, a new approach to measure innovativeness is discussed that could be employed by innovativeness researchers in the future. It would benefit from recent progress in neuroscience and would not rely on classical self-report questions but on empirical data on the candidate's brain activity in response to external stimuli.

Keywords: Innovativeness; IIS; recruiting; survey; EEG.

Received: January 2023. Accepted: March 2023.

INTRODUCTION

Our modern world is currently facing existential crisis after existential crisis (Kristalina 2022). From climate change, upcoming political destabilization, spreading of new diseases, demographic change, or globalization-induced wealth inequalities, a sheer endless list of problems overwhelms people around the globe (Renn et al. 2019, Homer-Dixon 2022; Kristalina 2022). Therefore, there is an ever-growing demand for people with an innovative mindset to adapt to these changes, as we define individual innovativeness as the openness of a person to new ideas and change (adapted from Agarwal 1998). This new reality especially affects companies and requires them to offer novel solutions to present and future problems (Stauffer 2016). Moreover, recent studies have shown that the success of a company is directly correlated with its ability to find and attract innovative employees, as they make the company more adaptive to changes in market needs (Shipton 2005, Sarros 2008).

However, defining and measuring an employee's level of individual innovativeness represents a challenge for modern-day recruiters, especially when selecting new top performers to manoeuvre their companies in evermore competitive environments (Bharadwaj and Menon 2000; Stauffer 2016; Hirschman 1980).

To make it easier to identify innovative people the work presented here critically tests the standard approach to measure individual innovativeness. To this end we experimentally compare it to simpler metrics and check it for consistency. In the following, new methods to gauge individual innovativeness based on bibliographical information or brain activity measurements are discussed. The main questions to be answered in this work are: "*Why are standard metrics to measure individual innovativeness insufficient and can they be improved with alternative approaches such as using bibliographical information?*"

The paper is outlined as follows. After a review of already established methods and the description of the study design and data evaluation workflow, the main result is presented in terms of correlations between different innovativeness metrics. The discussion of these findings then leads to the proposal of a new method to measure innovativeness which does not suffer from the drawbacks of self-report surveys.

THEORETICAL BACKGROUND

The need for innovativeness

It has been established in several works that employees with an innovative mindset perform better and increase a company's success (Shipton 2005, Sarros 2008), which ultimately leads to the question: "*How can individual innovativeness be measured and how can one find innovative people?*"

Typical approaches that are applied by recruiters are based on behavioural assessments (Burch 2008),

situational judgment tests (Motodiwlo 1990), personality tests (Costa 1988) and interviews.

While individual innovativeness is not easy to define, past works have established notions such as a person's readiness to take risks (Cancion 1967) or ability to adapt to changes (Leavitt 1975). As mentioned in the introduction, in this manuscript individual innovativeness shall refer to the mindset of an individual being open to new ideas. This model is known as the early-adopter model and has been a standard way to classify an individual's response to e.g., technological changes such as the rise of the internet (Agarwal 1998).

Standard models to measure innovativeness

Over the past decade, different models were proposed to quantify innovativeness that we briefly review now. Innovativeness can for instance be measured based on cognitive abilities (De Jong and Den Hartog 2010), as well as problem-solving styles (Kirton 1976; Kirton 2003). According to Soutar, innovativeness can be described as a predisposition to accept innovation (Soutar and Ward 2008), while in the field of personality-related innovation research, considering the whole individual arose as the prevailing model (Menold et al. 2014). On the other hand, Hunter et al. see innovativeness as a combination of factors such as expertise, creativity, and divergent thinking (Hunter, Cushenbery, and Friedrich 2012), but did not deduce a tool to quantify innovativeness (Menold et al. 2014). Other models used in recruiting situations include the team climate inventory that relates innovativeness to team dynamics (Anderson et al. 1998) and the Innovation Potential Indicator (Patterson 2002, Burch 2008).

Nowadays, the most established instrument to study individual innovativeness is the individual innovativeness scale (IIS) introduced by Hurt et al. already in 1977 (Hurt, Joseph, and Cook 1977). It was developed by selecting a suitable set of Likert-type (Likert 1932) questions out of a larger set that was given to 231 college students. The authors selected those questions for the IIS that maximized the discrimination between low and high innovativeness, via principal components factor analysis. To give an example, the IIS would ask whether the candidate agrees with the statement "I enjoy trying out new things". The full question list can be found in the supplementary figure 3. The resulting 20-item inventory IIS is nowadays a standard psychology tool to quantify innovativeness in a broad range of settings ranging from analysing social media use (Aldadouh 2020) to evaluating general life satisfaction (Ali 2019). It has become the go-to metric for innovativeness studies (Goldsmith 1991, de Jong 2007), and will serve as the prototype for the established methods in this work.

Problems of the established methods

While the precision and accuracy of the established models are not sufficient, as discussed by Menold et al. (Menold et al. 2014, Ter Haar 2018), there is also an intrinsic problem. All the established models rely on asking the candidate questions which are answered in a self-report manner. This can lead to an unwanted bias in the results. The largest risk stems from the social-desirability bias (Furnham 1986). As being innovative is considered a positive character trait, people tend to overestimate their innovativeness when being asked. At least in a homogeneous sample, this risk could be mitigated by calibrating to the peer group, but it still renders the methods less objective.

Additionally, in many established models, such as the IIS, the 20 questions (see Table 1) are closely related, which raises the question whether there is redundancy in the standard test. To test this, the IIS was compared to the results of a single self-evaluation question, obtaining a very high correlation (see Experiment A below), which confirms the redundancy in the IIS method.

New Method 1: innovativeness from bibliographical data

As discussed above, a questionnaire alone is not sufficient to measure individual innovativeness. Hence, this work attempts to additionally use bibliographical information to predict innovativeness. Throughout psychology research, it is known that a mix of environmental factors and personal experiences influence an individual's mindset and behaviour (Zimmerman 2013; Elder Jr. 1998). Hence, one of the purposes of this work is to evaluate the importance of the individual's background for innovativeness by testing correlations of specific background questions (see experiment B below) with the established IIS.

Studies have shown that individuals who experienced a lack of personal advantages at an early stage, such as parental guidance, financial stability, or emotional support often develop these into big advantages resulting in more successful and creative individuals (Fernández-Díaz et al. 2021). Hence, the focus of the background questions is put on the educational, cultural, financial, and social background of the individuals. Note that bibliographical information has of course already been used by recruiters to evaluate innovativeness, but so far only in a qualitative and subjective way, while we investigate quantitative correlations between bibliographical factors and individual innovativeness.

New Method 2: innovativeness from empirical measurements of brain response to external stimuli

While *method 1* might provide additional insight when added to the standard methods, it also has its limitations. To reliably predict innovativeness based on

bibliographical features requires extensive knowledge about the individual and a large reference data set and will still only provide probabilistic predictions. What is clearly missing is an empirical method, that allows quantifying an individual's innovativeness in a reliable way, not prone to for instance the social desirability bias.

Condensed set of IIS Scale questions	*Contributes positively (+) or negatively (-) to innovativeness*
I am generally cautious about accepting new ideas.	-
I rarely trust new ideas until the vast majority of people around me accept them.	-
I am aware that I am usually one of the last people in my group to adopt something new.	-
I am reluctant to adopt new ways of doing things until I see them working for people around me.	-
I find it stimulating to be original in my thinking and behaviour.	+
I feel comfortable sticking to traditions and rules that have worked in the past.	-
I like the challenge of solving difficult problems.	+
I will only consider using new innovations after seeing somebody else using them.	-
I like to go after unanswered questions.	+
I often find myself sceptical of new ideas.	-

Table 1: Condensed form of standard IIS metric questions (Hurt 1977)

One such method could be the measurement of brain activity either via electroencephalographic measurements (EEG) (Teplan 2002) or functional MRI measurements (Logothetis 2013) in response to external stimuli. Impressive work into those directions has already been carried out (see review by Dietrich 2010). It has for instance been possible to identify certain regions of the brain that are active when producing innovative solutions to tasks (Fink 2009) and it has been possible to identify emotional responses from brain patterns (Coan 2004).

The practical innovativeness test that is envisioned here requires only an EEG device of the simplest type, as are readily available and affordable nowadays (LaRocco 2020). The test could consist of showing images of things that are considered innovative (rockets, smartphones etc.) to an individual while measuring its EEG response, which is then compared to the responses of a reference group of known levels of innovativeness.

If carried out correctly, this test should provide a direct, unbiased test of an individual's acceptance of innovative ideas.

Note that while performing EEG scans can add new and unbiased information to evaluate innovativeness, such results will still not be ideal. Artefacts and errors can lead to wrong outcomes (Lyon 2017); hence they should not be used as stand-alone but as complementary methods.

METHOD AND DATA

Survey design

As this work is part of the Innovation class of an MBA program, the authors do not have the means to test method 2 in practice. Instead, two experiments were designed to support the claim that the standard methods are not sufficient (A) and to test method 1 (B):

- *Experiment A* compares the standard IIS metric (see Table 1) to a new, alternative metric (called 'New Scale', see Table 2), as well as to a single self-evaluation question, to illustrate the redundancy in the standard methods.

- *Experiment B* tests *method 1* and hence attempts to find correlations between the innovativeness as measured by the IIS and bibliographical information (for questions see Table 3).

To perform these experiments, a survey comprised of 5 groups of questions was used (bibliographical questions, self-evaluation question, IIS metric, alternative metric called 'New Scale'). The complete question lists can be found in the supplementary material.

While the general background questions provide more information about the participants (age, profession education etc.), specific background questions were chosen based on the hypothesis that certain environmental factors and experiences might influence an individual's personality and mindset, according to *method 1*. The self-evaluation question reads simply "*How innovative do you see yourself?".* For the IIS benchmark metric, the compact version of the standard IIS scale question set was used.

Finally, for the 'new scale', the questions are a combination of questions to capture personality traits following the Big-5 model (Tupes 1992), the four-factor model from the innovation potential indicator (Burch 2008), and a scenario-based questions.

Table 2: Overview of questions comprising the 'New Scale' metric: The sign of the measured Pearson correlation with the standard IIS metric confirms the assumption whether the question contributes positively or negatively to innovativeness. The high p-values are due to the small sample size of 30 individuals. The two statistically significant items (p-value < 0.05) are marked.

"New Scale" questions	*Hypothesis whether question correlates (+) or anti-correlates (-) with innovativeness*	*Measured correlation with ISS scale*	*p-value assuming 95% confidence interval*
I am willing to take risks for my own ideas	+	+ 0.36	0.05
I like to plan my days in detail in advance	-	- 0.04	0.83
I like to do routine tasks	-	- 0.17	0.36
In my work or study, I prefer to follow the rules that have been set	-	**- 0.55**	**0.002**
In my work or study, I often question people´s views, opinions	+	**+ 0.48**	**0.007**
When I try something new, I first make sure that it'll work.	-	- 0.17	0.35
I am ready to spend extra time on a task to find an optimal solution even though and easy solution already exists	+	+ 0.33	0.08
I feel passionate about my current work	+	+ 0.22	0.23
Scenario: If the new idea I applied did not work, I'd discard it and search for a new solution and keep working on it.	+	+ 0.02	0.91
I find it easy to convince others of my ideas	+	- 0.18	0.35
I like to approach a problem from many different angles	+	+ 0.28	0.14
Results are more important than the way they are obtained	-	- 0.21	0.28

Table 3: Overview of specific background questions aimed at determining factors driving innovativeness and their correlation with the standard IIS scale: Due to small sample size of 30 most of the correlations are not statistically significant, but the one that is, was highlighted.

Bibliographical Background Question	*Measured correlation with ISS scale*	*p-value assuming 95% confidence interval*
Do you prefer chocolate over vanilla ice cream?	+ 0.16	0.40
Do you think that you live in a social bubble?	- 0.11	0.57
Do any of your parents have an academic degree?	+ 0.03	0.87
Did your family have financial stability?	- 0.23	0.23
Do you have siblings or pets?	- 0.25	0.18
Did your cultural background play a significant role in your career choice?	- 0.18	0.35
Were you satisfied with the number of friends you had during school?	- 0.11	0.56
Do your career choices differ significantly from those of your friends?	**+ 0.40**	**0.03**
Have you ever invented something new or came up with a start-up idea?	+ 0.29	0.12
Were you a motivated student in school?	**- 0.30**	**0.10**
Was any of your obtained degrees with honors?	+ 0.02	0.91
Did you already have a career goal in mind during high school?	- 0.13	0.51

Sample composition

The sample group mainly comprises MBA-course participants, alumni, PhD students, and young professionals (see Figure 1). This sample group is interesting because all individuals share similar academic education and professional success but have different personal backgrounds. The survey was carried out purely online in self-report form. In total 30 people responded to all questions with most of them being 20-30 years old and holding a master's degree.

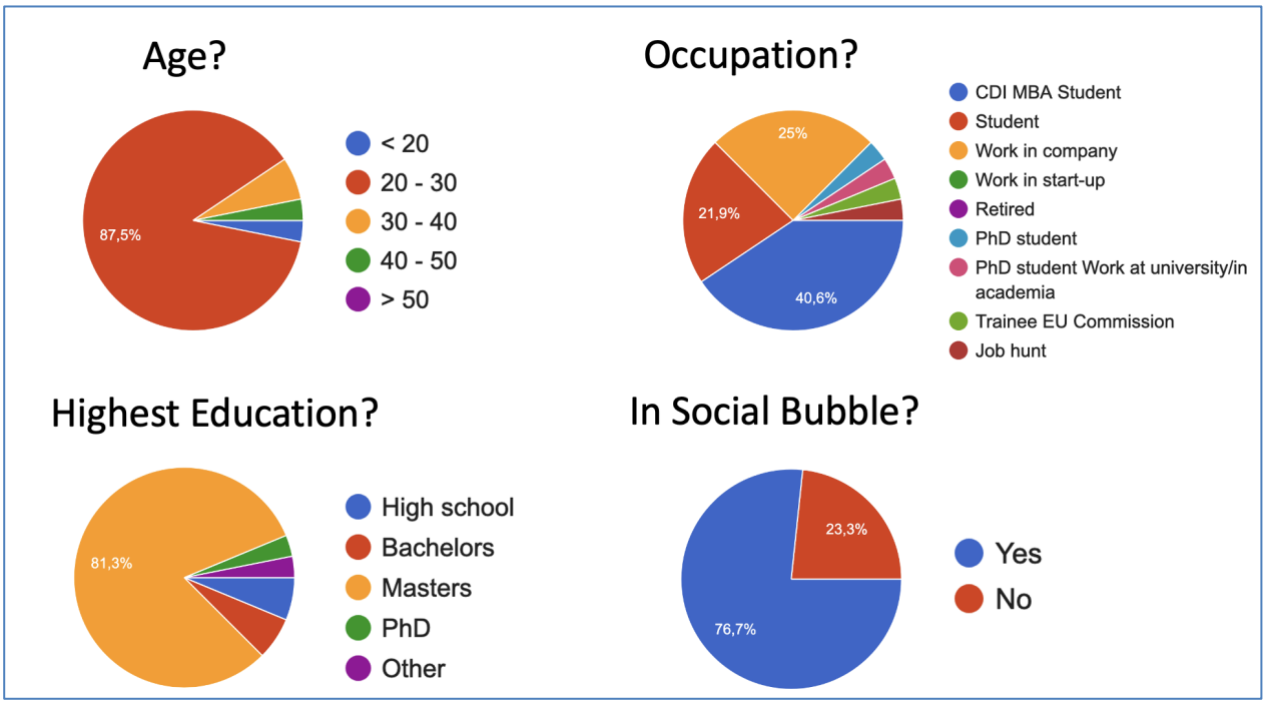

Fig. 1: Overview of sample composition. 30 participants in total.

Data treatment

The different innovativeness scales were computed from the answers to the Likert scale questions by simply adding the results. Since some questions are inversely formulated (a high agreement indicates low innovativeness), their answers need to be subtracted. While the original IIS publication (Hurt, Joseph, and Cook 1977) contains the information about which answers are added and which are subtracted, this was initially assumed for the 'new scale' innovativeness measure here but was later confirmed by the correlations with the other metrics. To compare the different metrics, they were then individually normalized such that a value of 0 corresponds to the minimum achievable test result (no innovativeness) and a value of 1 corresponds to the maximum achievable test result (maximum innovativeness).

All correlations in this work were calculated using Pearson correlation coefficients (Benesty 2009) which assume linear correlations. Since these coefficients are normalized, they are invariant under rescaling of the data, therefore the aforementioned normalization does not influence the calculated correlation results. To calculate correlations for questions with "yes/no" answers, they were transformed into numeric data by associating 'yes' ('no') with '1' ('0').

To interpret the correlation results, one should note that setting a fixed threshold of the Pearson coefficient is somewhat arbitrary and depends on the context (Schober 2018). One can however use it to determine the items of highest correlation. Concerning the statistical significance, assuming bivariate normal distributions and the standard confidence interval of 0.95%, the correlation coefficients can be interpreted via hypothesis tests. Hereby, the stated p-value indicates the probability that also fully uncorrelated data can explain the calculated Pearson coefficient by random chance and should therefore be by convention < 0.05 for significance.

RESULTS

Sanity checks

First, the validity of the assumptions about the 'new scale' metric were tested. As expected, all results for questions in which a positive (negative) answer contributes positively (negatively) to innovativeness showed a positive (negative) correlation with the standard IIS scale (see Table 2). This confirms our initial hypothesis in the metric design about which answers

must be added and which subtracted. One can however observe that no correlation coefficient is larger than 0.6, and only two items have p-values small enough to be considered statistically significant. The highest correlation with the standard method result is observed for the statement "I often question other people's views and opinions" (p-value 0.002) and the strongest anti-correlation is found with a coefficient of -0.55 for the statement "*In my work, I usually follow the rules*" (p-value 0.007).

As a first comparison of the metrics, the average innovativeness values can be compared. For the standard IIS scale, an average individual innovativeness value of 0.72 +- 0.02 was calculated for the 30 participants, which is comparable with the average values for the other two metrics (see Table 4).

One can also compare two subgroups (students currently enrolled in the CDI MBA program and those not enrolled), but no significant difference in innovativeness was found between them (Table 4).

Table 4: Sample average of innovativeness scales for two subgroups of participants

Average Innovativeness Scores	CDI-MBA fellows	Other
IIS Scale	0.72 +- 0.03	0.71 +- 0.02
Self-Evaluation Question	0.60 +- 0.07	0.65 +- 0.03
'New Scale'	0.62 +- 0.02	0.62 +- 0.02

In *experiment A* the 3 different innovativeness metrics were compared. The scatter plot (see Figure 2) confirms the positive correlation, which is however not perfect, as indicated by the Pearson coefficients < 1 in the inset. Here, all Pearson coefficients are statistically significant with a calculated p-value smaller than 0.1%.

Note that the single self-evaluation question has a high correlation with the standard IIS scale (Pearson coefficient of 0.62) and the "new scale" a slightly lower, but still clearly positive correlation with the IIS (Pearson coefficient of 0.47). It is remarkable that a single question of the type "*How innovative are you?"* captures almost all the information that is obtained via the established IIS scale, as will be discussed further below.

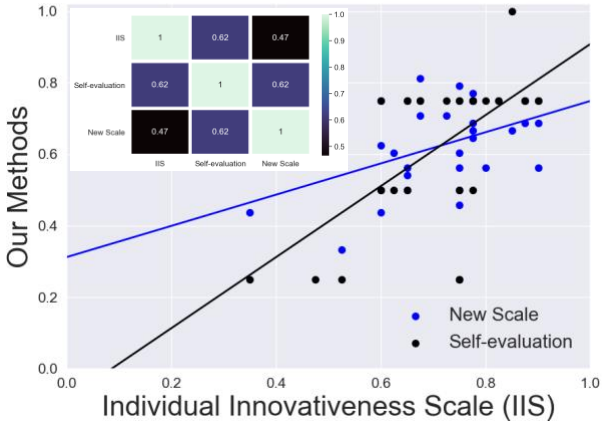

Fig. 2: Scatter Plot of Experiment A: Self-evaluation metric (orange) and 'new scale' metric (blue) vs standard IIS metric indicates positive correlation. The inset shows the calculated Pearson correlation coefficients of which all p-values are <0.001.

Then, for *experiment B*, looking at the Likert scale-based background questions reveals correlations between certain bibliographical driving factors and the IIS score (Table 3). However, most of the selected background questions showed no statistically significant correlations with innovativeness for this sample size as indicated by the high p-values.

The highest correlation with innovativeness was obtained for the question "*Do your career choices differ from those of your friends?"* (Pearson correlation coefficients of +0.4, p-value 0.03) while the question "*Were you a motivated student in high school?"* anti-correlates with innovativeness (Pearson coefficient of -0.3, p-value 0.1). Thus, based on these findings being an unmotivated high school student with untypical career choices is related to being more innovative. From all the other driving factors statistically significant correlations could not be obtained.

DISCUSSION

In *experiment A* different innovativeness metrics were compared. To do that, a personal innovativeness score comprised of 12 Likert-style questions was developed (the 'new scale') and correlated with the standard IIS. The results were obtained by surveying over 30 college students and recent graduates.

The quantitative analysis revealed that the 'new scale' score correlated positively with the standard IIS scale in a statistically significant way and the assumptions of whether each single question contributes positively or negatively to the score were confirmed.

Additionally, the correlations revealed that a single self-evaluation question captures already most of the information that the standard IIS scale gives. This underlines some of the problems of the standard methods

to measure individual innovativeness and can be potentially explained by the fact that most participants assess their level of innovativeness accurately. An alternative explanation could however be that the answers are to a large extent influenced by the response bias that is common in self-report surveys. Here, participants who think of themselves as being innovative, also select the answers of which they expect that it reflects their level of innovativeness. This finding also questions the necessity of conducting a full IIS survey if a single question is almost as good. While surveys are already an easy and cheap way to get an idea of a candidate's innovativeness, asking a single self-evaluation question will most likely give similar results. In addition, the accuracy of the single self-assessment question could be further improved by using a finer scaling of the possible answers (e.g., 1 to 10 instead of 1 to 5).

In addition to the full scales, the survey also contained specific background questions to improve the innovativeness measure (*experiment B*). However, in contrast to the statistically significant score correlations, the sample size of 30 was not large enough for statistically significant results for the background question correlations. The only significant finding was that being not challenged in high school is positively correlated with an innovative mindset.

This illustrates that *method 1* does not provide the expected advantage when measuring innovativeness. On the other hand, the proposed *method 2* (see above) might complement the standard ways of measuring innovativeness by using brain activity patterns as it does not suffer from the bias of self-report surveys.

CONCLUSION

The purpose of this paper was to critically compare different scales for assessing individual innovativeness since nowadays (and even more in the future) we face an increasing need for innovative people, in a world dominated by volatility. We experimentally found indications that a single self-report question contains almost the same amount of information as the standard IIS scale, supporting our hypothesis that there is redundancy and bias in the established methods.

Two other methods were therefore proposed in this work. *Method 1*, which uses bibliographical information to provide predictions of individual innovativeness, did not pay out in practice. The small sample size rendered most of the correlations insignificant. In case this was repeated on a much larger sample, a follow-up project could be, to then use machine learning approaches to predict the level of personal innovativeness based on extensive biographical data. Alternatively, the proposed method 2, that relies on measuring the brain activity in response to external stimuli was not carried out here but might provide further insight in the future and ultimately answer the question how innovative an individual is.

ACKNOWLEDGEMENTS

We thank Prof. Jimmi Normann Kristiansen for encouraging this project and the Collège des Ingénieures for support. We also acknowledge valuable discussions with Catarina Batista and thank all participants of our survey.

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