



# Improving the Big Five Inventory-2 in an Italian context using Rasch Analysis (BFI-2-R)

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## Abstract

The Big Five Inventory-2 (BFI-2) is one of the most used questionnaires to assess personality traits. Its main strength regards the possibility of distinguishing the five traits into 15 facets. Despite its extended usage and validation, there is still room for research to explore its structure and potential. For instance, an examination of the facets through Rasch Analysis (RA) has not been developed yet. We investigated the psychometric properties of the BFI-2 by applying the RA (obtaining the BFI-2-R), in addition to traditional analyses, in an Italian sample of 5362 adults. First, we conducted five confirmatory factor analyses, which supported the three-facet structure of each of the five traits. This structure resulted invariant at the scalar level across sex. Second, for each facet we checked and confirmed the necessary assumptions for applying the RA (i.e., about monotonicity, local independence, unidimensionality, and differential item functioning). We then found that our data fit the Rasch model for each facet. Finally, based on the Rasch scores, we documented the discriminant and convergent validity of the BFI-2-R. Overall, the findings support the goodness of the BFI-2-R and permit to extend research on the Big Five with an instrument considering the properties of fundamental measurement.

**Keywords** Big Five Inventory-2 · Personality assessment · Factor analysis · Sex invariance · Rasch analysis

## Introduction

The Big Five Inventory-2 (BFI-2; Soto & John, 2017) is a widespread tool for assessing personality traits, distinguishing 15 facets. Notwithstanding its large diffusion, it is still possible to improve its psychometric properties. We used the Rasch Analysis (RA; Kline, 1998) to transform the BFI-2 into an instrument formed by interval scales with the logit as the unit of measurement (obtaining the Big Five Inventory-2 Rasch Analysis, BFI-2-R). The application of RA allows for the construction of measurement instruments with properties similar to those used in the so-called Hard Sciences. According to them, a measure can be defined as the ratio between a quantity to be measured (denoted by  $Q$ ) and a unit

magnitude (denoted by  $q$ ) of the same kind as  $Q$  (Emerson, 2008), as expressed in formula 1:

$$r = Q/q \quad (1)$$

This formula unveils key characteristics of a well-defined scientific measure: (1) A unit of measurement is essential: Without a designated unit  $q$ , like centimeters (cm) or seconds (s), a measurement has no meaning. Therefore, a measured value  $r$  must always be accompanied by its corresponding unit (e.g., 12 cm or 23 s); (2) Unidimensionality: The equation only has one variable in the numerator  $Q$ , signifying that only a single property can be measured during a single measurement; (3) Invariance: The value  $r$  depends solely on the ratio between  $Q$  and  $q$ . This means that external factors, like the specific characteristics of the object being measured, the measuring instrument used, or the surrounding conditions, do not influence the measurement itself; (4) Linearity: Since the unit  $q$  is fixed, the measure  $r$  has a linear relationship with the quantity  $Q$ . This means that any change in  $Q$  results in a corresponding change in  $r$  that follows a straight-line pattern.

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## Advantages of Hard Sciences measurement

Defining a measure as described brings several advantages by allowing: (1) All mathematical operations: Measured values can be subjected to all fundamental mathematical operations— addition, subtraction, multiplication, and division; (2) A clearer picture of change: The linear link between a measure and its variable makes it easy to compare and understand how things change; (3) A glimpse into the future: By leveraging the linear relationship, we can predict future values of a variable based on current data; (4) Powerful statistics: The linearity of measurements is a cornerstone for using parametric statistics. These sophisticated methods allow us to analyze data in a more nuanced way, leading to deeper insights.

Differently, in the bio-psycho-social sciences, the variables of interest are usually quantified using questionnaires that do not have formula 1 and its consequences as a reference. This raises doubts about the quality of their quantifications (Ferguson et al., 1940). However, it is possible to bring the rigor of Hard Sciences even to the bio-psycho-social context (Luce & Tukey, 1964) thanks to the application of RA (Kline, 1998).

## The Rasch Analysis

The RA (Bond et al., 2021) overcomes some critical issues concerning traditional classical test theory approaches by prioritizing the objective measurement of latent factors according to the principles of fundamental measurement (for details about RA see Supplemental Materials, section SM1). The latter are usually respected by the physical and natural sciences but rarely by psychology. The main advantages of the RA concern its objectivity, validity, and stability (Burro, 2016; see paragraph SM1.1). Different from the classical test theory, using the RA, the items' capacity to quantify the measured constructs does not depend on the specific characteristics of the selected sample; moreover, the participants' quantified characteristics do not depend on the specific instrument used. As a consequence, the responses are constant over time. Therefore, the RA makes quantifying psychological aspects and inter-individual differences more rigorous.

The application of the RA presupposes the respect of some requirements about internal construct validity, namely monotonicity, local independence, unidimensionality, and absence of differential item functioning (DIF); however, their violation can be solved through some recursive steps (see paragraph SM1.2). Further phases include the analysis of items performance and misfitting participants (see paragraph SM1.3), the reliability check (see paragraph SM1.4), and lastly, the analysis of the fit between data and

the Rasch model (see paragraph SM1.5). By following these steps, sample-free and test-free measures are calculated for each item and participant using an interval logit scale. This means that the obtained items' measures are independent of the sample of participants used (sample-free) as well as that the participants' measures are independent of the administered items (test-free). The application of RA seems particularly promising in personality assessment contexts since it leads to measurements that are rigorous, precise, and not distorted.

## The Big Five Inventory-2

Assessing personality with psychometrically sound instruments is a key step to advancing research on its nature and correlates. One of the currently most used questionnaires is the BFI-2, which measures both traits and facets (Soto & John, 2017). Starting from a preliminary Italian translation (Lee et al., 2020), we investigated its basic properties in terms of factor structure and sex invariance, focusing on the facet-level. In addition to using classic factor analysis methods, we explored the personality facets using also RA. The latter offers the possibility of converting the raw BFI-2 scores in interval logit scales (Bond et al., 2021). This led to the BFI-2-R. The Rasch scores also allowed us to analyze and prove the discriminant and convergent validity of the BFI-2-R.

The five-factor model of personality includes a set of five broad trait dimensions or domains, often indicated as the Big Five, i.e., Extraversion, Agreeableness, Conscientiousness, Negative Emotionality (also called Neuroticism or Emotional Stability, based on its polar opposites), and Open-Mindedness (sometimes called Openness to Experience or Intellect). These domains are helpful in describing many relevant individual differences in people's patterns of thinking, feeling, and behaving (John et al., 2008) and have been largely investigated in terms of their correlates, antecedents, and consequences (Soto & John, 2017).

The BFI (John et al., 2008) measures the prototypical features of the five domains using 44 short and easy-to-understand English sentences. A revised version of the BFI, i.e., the BFI-2 (Soto & John, 2017), is a 60-item questionnaire that conforms to a hierarchical five domains, or traits, and 15 sub-domains, or facets, structure (see the list of the 15 facets in the 2.2 section). This hierarchical distinction in traits and facets has been used by many researchers (Costa & McCrae, 1995).

The advantages and disadvantages of conceptualizing a construct according to different degrees of breadth, as when we focus on traits and/or facets, are referred to as the bandwidth-fidelity tradeoff (John et al., 1991). On the one hand, defining a domain with a high bandwidth (e.g.,

Extraversion) has the advantage of summarizing a variety of information about human behavior and thus predicting a large number of relevant criteria, e.g., about cognitions, emotions, and motivation (John et al., 2008). On the other hand, a narrower definition (e.g., Sociability as a facet of Extraversion) guarantees high fidelity, that is, precise descriptions of specific behaviors and accurate predictions of more specific psychological constructs (Paunonen & Ashton, 2001). For these reasons, the BFI-2, where the five traits are conceptualized having the facet-level distinction in mind, has a series of advantages as compared to the BFI, and overcomes some of its technical limitations (John et al., 2008). The BFI had a relatively low number of items for each trait; an unbalanced representation of the traits (e.g., for Conscientiousness, there were more items for Productiveness than for Organization); and some items could relate to more than one facet (e.g., “Does a thorough job” is an aspect relevant for both Productiveness and Organization).

The original BFI also suffered from people’s acquiescent response style, i.e., the tendency to consistently agree or disagree with the items independently of their content. This limitation was caused by an unequal number of true-key items (i.e., items that are always true) and false-key items (i.e., items that are false or reversed). Individual differences concerning this style can negatively impact the internal consistency of a test (Soto et al., 2008). The BFI-2 solved this problem by including a balanced number of true-key and false-key items, at both the trait and facet-level. Finally, a further advantage of the BFI-2 is the ease of understanding its items that consist of short sentences including an adjective relevant to the trait (e.g., “dominant”) and then clarifying its meaning by adding a synonym, a definition, or a context (e.g., “is dominant, acts as a leader”). In this way, the items benefit from the simplicity and brevity of adjective ratings, but at the same time solve the limitations of adjective usage relating to their possible ambiguous or multiple meanings (Goldberg & Kilkowski, 1985).

The BFI-2 was validated in various different languages (e.g., Croatian, French, German, Russian, and Spanish), and its psychometric properties were widely supported; its structure resulted substantially invariant across sex (Gallardo-Pujol et al., 2022; Hausding & Horstmann, 2023; Lignier et al., 2023; Shchebetenko et al., 2020), but there were some exceptions. For instance, scalar invariance was not always found for traits such as Extraversion and Agreeableness, or for some specific facets (Gallardo-Pujol et al., 2022; Hausding & Horstmann, 2023). Moreover, to our knowledge, a psychometrically sound version of the BFI-2 based on the RA has not been published yet, as well as an Italian validation. However, the instrument might benefit from it, for the mathematical reasons explained in the previous sections.

## The current study

The overall goal of this study was to apply the RA to the BFI-2 (Soto & John, 2017), to improve its measurement properties, focusing on the facet-level. By developing the BFI-2-R, we filled in two gaps in current literature, concerning (a) the lack of instruments measuring the Big Five at the facet-level, while respecting the properties of fundamental measurement, and (b) the presence of inconsistent findings about sex invariance of the BFI-2. We had three main aims.

First, we aimed to test the factorial structure of each of the five traits of the BFI-2 administered in the Italian language (aim 1). We expected each trait to be characterized by a three-facet structure (Hypothesis 1a, H1a). We also expected each three-facet trait to be invariant across sex (H1b).

Second, we aimed to apply the RA for each facet, after checking the assumptions for its correct use (aim 2). For each facet, we verified that the assumptions about monotonicity, local independence, unidimensionality, and DIF were respected (H2a). We then verified whether each facet fit the Rasch model (H2b).

Third, we aimed to explore the discriminant and convergent validity of the BFI-2-R (aim 3). We expected higher correlations between the three facets of each trait and lower correlations between the five traits (H3a). Finally, we expected each BFI-2-R trait to be related to the corresponding trait (H3b) as measured by another instrument.

## Method

### Participants

A convenience sample of 5362 Italian adults ( $M_{age} = 41.85$  years,  $SD = 13.56$ ; 60% females), with a wide range of socio-economic status, was recruited during courses at the University of Verona and through snowball sampling. The research was approved by the Ethic Committee of the Department of Human Sciences, University of Verona (protocol number: 635556). We obtained informed consent from all participants.

### Materials

Two Big Five inventories were administered in Italian. In both cases, the respondents were presented a series of statements (items) and asked to rate how true each statement was in describing the respondent (ratings given on a five-point scale, ranging from 1 = *disagree strongly* to 5 = *agree strongly*).

### Big Five Inventory-2 (BFI-2)

We started from a preliminary Italian translation of the BFI-2 developed for the International Situations Project (Lee et al., 2020), on which we applied a further back-translation procedure from English to Italian and back from Italian to English (see Table 1 for instructions, items, and response modality in the English and Italian versions). Each trait is assessed by 12 items (four items for each of the three facets of the trait) for a total of 60 items. The facets are: Sociability, Assertiveness, and Energy Level for the trait Extraversion; Compassion, Respectfulness, and Trust for the trait Agreeableness; Organization, Productiveness, and Responsibility for the trait Conscientiousness; Anxiety, Depression, and Emotional Volatility for the trait Negative Emotionality; and Intellectual Curiosity, Aesthetic Sensitivity, and Creative Imagination for the trait Open-Mindedness.

### Big Five Inventory-10 (BFI-10)

We utilized the Italian adaptation (Guido et al., 2015) of the BFI-10. It includes 10 items, with two items for each of the five traits (Extraversion, Agreeableness, Conscientiousness, Emotional Stability, and Openness).

### Data analysis

We used the R software (version 4.4.0). To test HP1a, we ran five confirmatory factor analyses (CFA; lavaan R package, Rosseel, 2012), one for each trait, with three factors each. Considering the comparative fit index (CFI), the Tucker-Lewis index (TLI), the goodness-of-fit index (GFI), the adjusted goodness-of-fit index (AGFI), the root-mean-square error of approximation (RMSEA), and the standardized root-mean residual (SRMR) as fit-indexes, the threshold values were CFI, TLI, GFI, and AGFI  $\geq 0.95$ , and RMSEA and SRMR  $\leq 0.08$ , respectively (Hu & Bentler, 1999). To examine measurement invariance (MI) across sex (HP1b), we tested separate CFA models, keeping in mind that support for invariance requires  $\Delta CFI$  and  $\Delta TLI \leq 0.010$ , and  $\Delta RMSEA \leq 0.015$  for all invariance types (i.e., configural, metric, and scalar), while  $\Delta SRMR \leq 0.030$  for metric invariance and  $\Delta SRMR \leq 0.010$  for scalar invariance (Chen, 2007). Our sample size was appropriate (Kline, 2016), with a ratio between observations and parameters of 85:1 (5362 participants for 63 estimated parameters).

To test HP2, we checked the requirements about monotonicity, local independence, unidimensionality, and DIF (eRm R package, Mair & Hatzinger, 2007), and we adjusted the items in case they were not met (see paragraph SM1.2). We then checked item performance and misfitting participants (see paragraph SM1.3), reliability (see paragraph

SM1.4), and whether the data fit the Rasch model using the partial credit model (Masters & Wright, 1997; see paragraph SM1.5). Then, we transformed each facet's scores according to the conversion table into an interval logit scale.

To investigate HP3 about discriminant validity, we inspected bivariate correlations between the three facets for each trait, and between the five traits. To test convergent validity, we conducted bivariate correlations between each BFI-2-R trait score and BFI-10 trait score. We referred to Cohen's guidelines for interpreting correlations, with small, medium, or large effects indicating, respectively, by Pearson's  $r = 0.10$ ,  $0.30$ , and  $0.50$  (Cohen, 1988).

## Results

### Confirmatory factor analyses and measurement invariance (aim 1)

The reliability for each 4-item facet scale ranged from adequate to high (see Table SM2.1 for reliability values). The alpha/omega indexes for our data ranged from 0.61/0.62 to 0.85/0.85, with a mean of 0.69/0.70, respectively, in line with Soto and John (2017;  $0.65 < \alpha < 0.84$ ,  $M = 0.76$ ).

The internal factorial structure of each Big Five trait was also confirmed by the five CFA conducted on our data (using the diagonally weighted least squares, DWLS, estimator for ordinal data), considering three factors for each CFA— one for each facet. All the indices had a very good fit to the data (Table SM2.2), supporting the three-facet structure for each Big Five trait. Figure 1 represents the CFA path diagram, with the standardized factor loadings and explained variance at the facet-level ( $R^2$ ; see Table SM2.1 for intercorrelations and descriptive statistics).

The MI for each of the five three-facet models across sex was also confirmed for all the levels of invariance, i.e., configural, metric, and scalar (Table SM2.3).

### Rasch analysis (aim 2)

We start here by reporting the results of testing Rasch requirements for each facet of each Big Five factor (see paragraph SM1.2). First, the inspection of the person-item maps (to check for item monotonicity) revealed a lack of monotonicity for two facets of Agreeableness (Compassion: item 32; Respectfulness: items 7 and 52), one facet of Conscientiousness (Responsibility: item 43), and one facet of Open-Mindedness (Intellectual Curiosity: items 25 and 55), for a total of 6 items. In all these cases, rescoring was needed (see Table 2 for the rescoring rules), and monotonicity was at the end guaranteed (see Figure SM2.1 for the maps before and after the rescoring). Second, local

**Table 1** Instructions, items, and response scale for administering the BFI-2-R in the English and Italian versions. Instructions: “Here are a number of characteristics that may (or may not) apply to you. For example, do you agree that ‘you are someone who likes to spend time with others’? Please indicate with a cross the extent to which you agree or disagree with each of the following statements” (“Ecco una serie di caratteristiche che potrebbero (oppure no) applicarsi a te. Ad esempio, sei d’accordo nel dire che ‘sei una persona a cui piace trascorrere del tempo con gli altri’? Segna con una croce il grado di accordo o disaccordo con ognuna delle seguenti dichiarazioni” in Italian). “I’m a person that...” (“Sono una persona che...” in Italian)

Item ID	English items	Italian items	Level of agreement				
1	Is outgoing, sociable	È estroversa, socievole	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d’accordo	(Agree strongly) Fortemente d’accordo
2	Is compassionate, has a soft heart	È compassionevole, ha il cuore tenero	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d’accordo	(Agree strongly) Fortemente d’accordo
3	Tends to be disorganized	Tende a essere disorganizzata	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d’accordo	(Agree strongly) Fortemente d’accordo
4	Is relaxed, handles stress well	È tranquilla, gestisce bene lo stress	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d’accordo	(Agree strongly) Fortemente d’accordo
5	Has few artistic interests	Ha pochi interessi artistici	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d’accordo	(Agree strongly) Fortemente d’accordo
6	Has an assertive personality	Ha una personalità decisa, che sa farsi ascoltare	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d’accordo	(Agree strongly) Fortemente d’accordo
7	Is respectful, treats others with respect	È rispettosa, tratta gli altri con rispetto	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d’accordo	(Agree strongly) Fortemente d’accordo
8	Tends to be lazy	Tende a essere pigra	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d’accordo	(Agree strongly) Fortemente d’accordo
9	Stays optimistic after experiencing a setback	Rimane ottimista di fronte agli ostacoli	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d’accordo	(Agree strongly) Fortemente d’accordo
10	Is curious about many different things	È incuriosita da molte cose diverse	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d’accordo	(Agree strongly) Fortemente d’accordo
11	Rarely feels excited or eager	Raramente si sente elettrizzata o appassionata	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d’accordo	(Agree strongly) Fortemente d’accordo
12	Tends to find fault with others	Tende a trovare difetti negli altri	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d’accordo	(Agree strongly) Fortemente d’accordo
13	Is dependable, steady	È regolare, costante	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d’accordo	(Agree strongly) Fortemente d’accordo
14	Is moody, has up and down mood swings	È lunatica, ha sbalzi d’umore	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d’accordo	(Agree strongly) Fortemente d’accordo
15	Is inventive, finds clever ways to do things	È inventiva, trova modi ingegnosi per fare le cose	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d’accordo	(Agree strongly) Fortemente d’accordo
16	Tends to be quiet	È tendenzialmente silenziosa	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d’accordo	(Agree strongly) Fortemente d’accordo
17	Feels little sympathy for others	Prova poca empatia per gli altri	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d’accordo	(Agree strongly) Fortemente d’accordo

**Table 1** (continued)

Item ID	English items	Italian items	Level of agreement				
18	Is systematic, likes to keep things in order	È sistematica, ama tenere le cose in ordine	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d'accordo	(Agree strongly) Fortemente d'accordo
19	Can be tense	Può essere nervosa	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d'accordo	(Agree strongly) Fortemente d'accordo
20	Is fascinated by art, music, or literature	È affascinata dall'arte, dalla musica, o dalla letteratura	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d'accordo	(Agree strongly) Fortemente d'accordo
21	Is dominant, acts as a leader	È dominante, agisce da leader	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d'accordo	(Agree strongly) Fortemente d'accordo
22	Starts arguments with others	Provoca litigi con gli altri, attacca brighe	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d'accordo	(Agree strongly) Fortemente d'accordo
23	Has difficulty getting started on tasks	Fa fatica a iniziare un lavoro	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d'accordo	(Agree strongly) Fortemente d'accordo
24	Feels secure, comfortable with self	Si sente sicura, a proprio agio con se stessa	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d'accordo	(Agree strongly) Fortemente d'accordo
25	Avoids intellectual, philosophical discussions	Evita discussioni intellettuali, filosofiche	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d'accordo	(Agree strongly) Fortemente d'accordo
26	Is less active than other people	È meno attiva di altre persone	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d'accordo	(Agree strongly) Fortemente d'accordo
27	Has a forgiving nature	È, di natura, incline a perdonare	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d'accordo	(Agree strongly) Fortemente d'accordo
28	Can be somewhat careless	Può essere un po' sbadata	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d'accordo	(Agree strongly) Fortemente d'accordo
29	Is emotionally stable, not easily upset	È emotivamente stabile, non si turba facilmente	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d'accordo	(Agree strongly) Fortemente d'accordo
30	Has little creativity	Ha poca creatività	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d'accordo	(Agree strongly) Fortemente d'accordo
31	Is sometimes shy, introverted	Qualche volta è timida, introversa	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d'accordo	(Agree strongly) Fortemente d'accordo
32	Is helpful and unselfish with others	È di aiuto e generosa con gli altri	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d'accordo	(Agree strongly) Fortemente d'accordo
33	Keeps things neat and tidy	Tiene le cose con cura	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d'accordo	(Agree strongly) Fortemente d'accordo
34	Worries a lot	Si preoccupa molto	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d'accordo	(Agree strongly) Fortemente d'accordo
35	Values art and beauty	Apprezza l'arte e la bellezza	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d'accordo	(Agree strongly) Fortemente d'accordo
36	Finds it hard to influence people	Trova difficile influenzare le persone	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d'accordo	(Agree strongly) Fortemente d'accordo

**Table 1** (continued)

Item ID	English items	Italian items	Level of agreement				
37	Is sometimes rude to others	Qualche volta è scortese con gli altri	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d'accordo	(Agree strongly) Fortemente d'accordo
38	Is efficient, gets things done	È efficiente, ottiene risultati	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d'accordo	(Agree strongly) Fortemente d'accordo
39	Often feels sad	Si sente spesso triste	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d'accordo	(Agree strongly) Fortemente d'accordo
40	Is complex, a deep thinker	È complessa, riflette molto	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d'accordo	(Agree strongly) Fortemente d'accordo
41	Is full of energy	È piena di energie	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d'accordo	(Agree strongly) Fortemente d'accordo
42	Is suspicious of others' intentions	È sospettosa delle intenzioni altrui	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d'accordo	(Agree strongly) Fortemente d'accordo
43	Is reliable, can always be counted on	È affidabile, una persona su cui si può sempre contare	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d'accordo	(Agree strongly) Fortemente d'accordo
44	Keeps their emotions under control	Tiene sotto controllo le proprie emozioni	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d'accordo	(Agree strongly) Fortemente d'accordo
45	Has difficulty imagining things	Ha difficoltà a immaginare le cose	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d'accordo	(Agree strongly) Fortemente d'accordo
46	Is talkative	Parla molto	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d'accordo	(Agree strongly) Fortemente d'accordo
47	Can be cold and uncaring	Può essere fredda e insensibile	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d'accordo	(Agree strongly) Fortemente d'accordo
48	Leaves a mess, doesn't clean up	Lascia il caos, non pulisce	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d'accordo	(Agree strongly) Fortemente d'accordo
49	Rarely feels anxious or afraid	Raramente si sente ansiosa o spaventata	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d'accordo	(Agree strongly) Fortemente d'accordo
50	Thinks poetry and plays are boring	Pensa che la poesia e le opere teatrali siano noiose	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d'accordo	(Agree strongly) Fortemente d'accordo
51	Prefers to have others take charge	Preferisce che siano gli altri a prendere il comando	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d'accordo	(Agree strongly) Fortemente d'accordo
52	Is polite, courteous to others	È educata, gentile con gli altri	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d'accordo	(Agree strongly) Fortemente d'accordo
53	Is persistent, works until the task is finished	È tenace, lavora fino a quando un compito è finito	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d'accordo	(Agree strongly) Fortemente d'accordo
54	Tends to feel depressed, blue	Tende a sentirsi depressa, giù di morale	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d'accordo	(Agree strongly) Fortemente d'accordo

**Table 1** (continued)

Item ID	English items	Italian items	Level of agreement				
55	Has little interest in abstract ideas	Si interessa poco di idee astratte	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d'accordo	(Agree strongly) Fortemente d'accordo
56	Shows a lot of enthusiasm	Mostra molto entusiasmo	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d'accordo	(Agree strongly) Fortemente d'accordo
57	Assumes the best about people	Pensa il meglio delle persone	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d'accordo	(Agree strongly) Fortemente d'accordo
58	Sometimes behaves irresponsibly	Talvolta si comporta in modo irresponsabile	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d'accordo	(Agree strongly) Fortemente d'accordo
59	Is temperamental, gets emotional easily	È volubile, si lascia sopraffare dalle emozioni	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d'accordo	(Agree strongly) Fortemente d'accordo
60	Is original, comes up with new ideas	È originale, propone nuove idee	(Disagree strongly) Fortemente in disaccordo	(Disagree a little) Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little) Un poco d'accordo	(Agree strongly) Fortemente d'accordo

Fortemente in disaccordo=Disagree strongly; Un poco in disaccordo=Disagree a little; Né in accordo, né in disaccordo=Neutral, no opinion; Un poco d'accordo=Agree a little; Fortemente d'accordo=Agree strongly. BFI-2 English items and response scale labels correspond to the original version. Copyright 2015 by Oliver P. John and Christopher J. Soto. Reprinted with permission

independence was confirmed for each facet of each Big Five trait. The correlations between item residuals were always lower than 0.20 (see Table SM2.4 for correlation ranges). Third, unidimensionality (tested for each facet by running a principal component analysis on the correlations among the standardized residuals) was also supported. The eigenvalue of the first contrast was always lower than 2.00 (maximum value for Extraversion: 1.58; Agreeableness: 1.66; Conscientiousness: 1.69; Negative Emotionality: 1.87; Open-Mindedness: 1.53). Fourth, for each facet, the standardized P-DIF ranged between  $-0.10$  and  $0.10$  (see Table SM2.4 for standardized P-DIF ranges), indicating the absence of DIF with respect to sex.

We then explored items and persons' performance (see paragraph SM1.3). The items turned out to fit well the Rasch model: Both infit-MSQ and outfit-MSQ values were within the adequate range, i.e., between 0.50 and 1.50 (Table SM2.5). Regarding persons' performance, the percentage of misfitting participants was small for all the 15 facets, coherently with the predictions of the RA (maximum percentage for Extraversion: 3.47%; Agreeableness: 2.60%; Conscientiousness: 4.59%; Negative Emotionality: 3.44%; Open-Mindedness: 3.90%).

Concerning the reliability of each 4-item facet scale (see Table SM2.5 for the person separation reliability index, PSR, at the facet and trait-level), we found that the PSR ranged from 0.51 to 0.72, with a mean of 0.61. This can be caused by the low number of items for each scale. Nevertheless, the PSR for each trait ranged from 0.73 to 0.85, with a

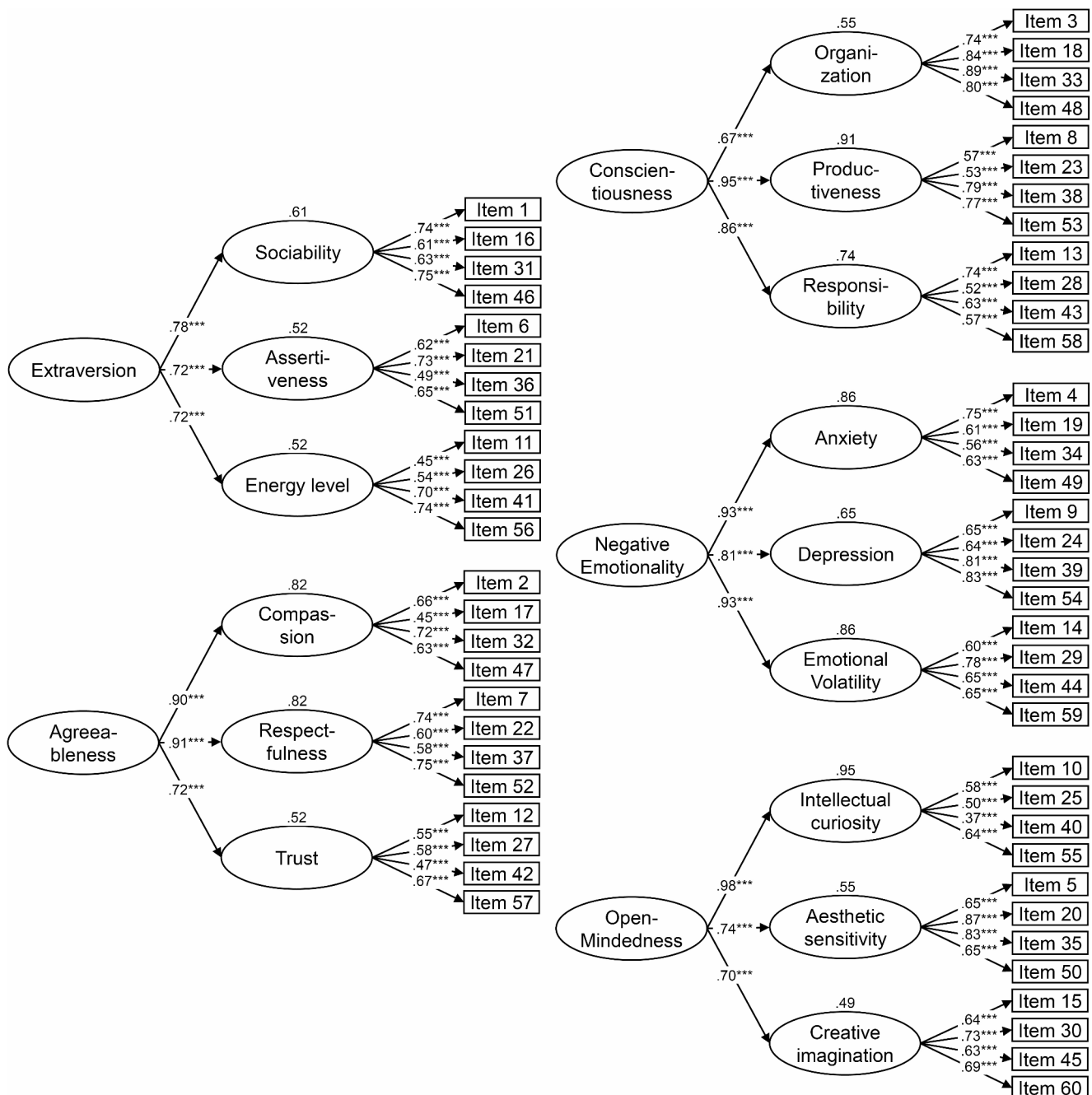
mean of 0.77, revealing adequate to good reliability at the trait-level.

Finally, Andersen's likelihood ratio test (LRT)—used to check the goodness-of-fit of each facet scale to the Rasch model (Andersen, 1973)—revealed that none of the 15 chi-square tests resulted significant (Table SM2.6). Therefore, the fit between our scales and the Rasch model was good.

At this point, for each facet, it was possible to transform the raw scores into Rasch scores, which function according to an interval logit scale. The four tables in this paper report the description of the four-step procedure to administer and score the BFI-2-R. In Table 1, we included the instructions, the items, and the response scale both in Italian and English. In Table 2, we reported how to score the responses to the 60 items, taking into account that some items must be reversed and indicating how to rescore the items for which there were violations of monotonicity. In Table 3, we described how to obtain a total raw score for each facet (and each trait), summing the scores of the four corresponding items. In Table 4, we inserted the conversion table that enables the transformation of the raw total scores into logit scores for each facet. To increase the usability of the instrument, we scaled the logit scores from 0 to 10. The score for each trait can be obtained by summing the scores of the corresponding facets.

### Discriminant and convergent validity (aim 3)

The analyses supported the discriminant validity of the BFI-2-R, considering both the facet and the trait-level (see



**Fig. 1** Three-facet factorial structure for each of the Big Five traits. The digits represent standardized factor loadings.  $R^2$  for the facets refers to the proportion of variance of the latent response explained by the predictors. \* $p < .05$ . \*\* $p < .01$ . \*\*\* $p < .001$

Table SM2.7 and SM2.8 for intercorrelations and descriptive statistics). For each trait, the correlations between the three facets, based on their Rasch scores, were positive and significant, with medium or large effects (similar to Soto & John, 2017, with inter-facet correlations of 0.53 and 0.55). Considering the composite score for each trait (calculated by summing up the Rasch scores of each facet) and examining the correlations between the five traits, we found that all correlations were significant (except between Negative

Emotionality and Open-Mindedness) and were generally small (again similar to Soto & John, 2017, averaging 0.16 and 0.19); they were also all positive except those involving Negative Emotionality.

The convergent validity of the BFI-2-R also emerged, as revealed by the correlations between the Rasch score traits and the BFI-10 scores. All the correlations were large and positive (Extraversion:  $r = 0.56$ ,  $p < .001$ ; Agreeableness:  $r = 0.57$ ,  $p < .001$ ; Conscientiousness:  $r = 0.67$ ,  $p < .001$ ;

**Table 2** Score attribution. The responses given in Table 1 should be scored according to this scheme. The attributed scores already take into account reversed and recoded items

Item ID	(Disagree strongly) Fortemente in disaccordo	(Disagree a little)Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little)Un poco d'accordo	(Agree strongly) Fortemente d'accordo	Notes
1	1	2	3	4	5	
2	1	2	3	4	5	
3	5	4	3	2	1	REVERSED
4	5	4	3	2	1	REVERSED
5	5	4	3	2	1	REVERSED
6	1	2	3	4	5	
7	1	2	2	3	4	RECODED
8	5	4	3	2	1	REVERSED
9	5	4	3	2	1	REVERSED
10	1	2	3	4	5	
11	5	4	3	2	1	REVERSED
12	5	4	3	2	1	REVERSED
13	1	2	3	4	5	
14	1	2	3	4	5	
15	1	2	3	4	5	
16	5	4	3	2	1	REVERSED
17	5	4	3	2	1	REVERSED
18	1	2	3	4	5	
19	1	2	3	4	5	
20	1	2	3	4	5	
21	1	2	3	4	5	
22	5	4	3	2	1	REVERSED
23	5	4	3	2	1	REVERSED
24	5	4	3	2	1	REVERSED
25	4	3	2	1	1	REVERSED, RECODED
26	5	4	3	2	1	REVERSED
27	1	2	3	4	5	
28	5	4	3	2	1	REVERSED
29	5	4	3	2	1	REVERSED
30	5	4	3	2	1	REVERSED
31	5	4	3	2	1	REVERSED
32	1	1	2	3	4	RECODED
33	1	2	3	4	5	
34	1	2	3	4	5	
35	1	2	3	4	5	
36	5	4	3	2	1	REVERSED
37	5	4	3	2	1	REVERSED
38	1	2	3	4	5	
39	1	2	3	4	5	
40	1	2	3	4	5	
41	1	2	3	4	5	
42	4	3	2	1	1	REVERSED, RECODED
43	1	2	3	4	5	
44	5	4	3	2	1	REVERSED
45	5	4	3	2	1	REVERSED
46	1	2	3	4	5	
47	5	4	3	2	1	REVERSED
48	5	4	3	2	1	REVERSED
49	5	4	3	2	1	REVERSED
50	5	4	3	2	1	REVERSED

**Table 2** (continued)

Item ID	(Disagree strongly) Fortemente in disaccordo	(Disagree a little)Un poco in disaccordo	(Neutral; no opinion) Né in accordo, né in disaccordo	(Agree a little)Un poco d'accordo	(Agree strongly) Fortemente d'accordo	Notes
51	5	4	3	2	1	REVERSED
52	1	1	2	3	4	RECODED
53	1	2	3	4	5	
54	1	2	3	4	5	
55	4	3	2	1	1	REVERSED, RECODED
56	1	2	3	4	5	
57	1	2	3	4	5	
58	5	4	3	2	1	REVERSED
59	1	2	3	4	5	
60	1	2	3	4	5	

REVERSED=this label indicates that the item score has already been reversed; RECODED=this label indicates that the item score has been modified, taking into account the violation of monotonicity

**Table 3** Total score calculation. Based on the indications in this scheme, it is possible to obtain (starting from the values obtained in Table 2) a raw total score for each participant for each facet, summing the scores of the indicated items

Traits (in English and Italian)	Facets (in English and Italian)	Facet Description	Item ID
Extraversion (Estroversione)	Sociability (Socievolezza)	It refers to a disposition to appreciate staying with people and looking for social interactions	1 + 16 + 31 + 46
	Assertiveness (Assertività)	It refers to a disposition to be outgoing, being able to express one's own position, and acting as a leader in social situations	6 + 21 + 36 + 51
	Energy Level (Livello di Energia)	It refers to a disposition to be energetic, passionate, and active	11 + 26 + 41 + 56
Agreeableness (Amicalità)	Compassion (Compassione)	It refers to a disposition to care for others, be empathetic, and comprehending others' feelings	2 + 17 + 32 + 47
	Respectfulness (Rispetto)	It refers to a disposition to be kind, respectful, and sensitive in social interactions	7 + 22 + 37 + 52
	Trust (Fiducia)	It refers to a disposition to be trusting, forgiving, and thinking the best about others	12 + 27 + 42 + 57
Conscientiousness (Coscienziosità)	Organization (Organizzazione)	It refers to a disposition to be well-organized, care for things, and systematic	3 + 18 + 33 + 48
	Productiveness (Produttività)	It refers to a disposition to be persistent, efficient, and goal-oriented	8 + 23 + 38 + 53
	Responsibility (Responsabilità)	It refers to a disposition to be steady, reliable, and accountable	13 + 28 + 43 + 58
Negative Emotionality (Emozionalità Negativa)	Anxiety (Ansia)	It refers to a disposition to experience negative emotions like worry, nervousness, and apprehension	4 + 19 + 34 + 49
	Depression (Depressione)	It refers to a disposition to experience sadness, hopelessness, and a negative mood	9 + 24 + 39 + 54
	Emotional Volatility (Volatilità Emotiva)	It refers to a disposition to experience quick and extreme emotional changes	14 + 29 + 44 + 59
Open-Mindedness (Apertura Mentale)	Intellectual Curiosity (Curiosità Intellettuale)	It refers to a disposition to consider more than one point of view and be intellectually curious	10 + 25 + 40 + 55
	Aesthetic Sensitivity (Sensibilità Estetica)	It refers to a disposition to appreciate beauty in different forms, like art, music, and literature	5 + 20 + 35 + 50
	Creative Imagination (Immaginazione Creativa)	It refers to a disposition to be creative, innovative, and imagine new experiences and ideas	15 + 30 + 45 + 60

**Table 4** Conversion of total scores into interval logit scores

Raw score	Logit score			Agreeableness				Conscientiousness				Negative Emotionality				Open-Mindedness			
	Extraversion	Assertiveness	Energy level	Compassion	Respectfulness	Trust	Organization	Productiveness	Responsibility	Anxiety	Depression	Emotional Volatility	Intellectual Curocity	Aesthetic Sensitivity	Creative Imagination				
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
5	1.253	1.09	1.144	1.19	1.366	1.174	1.127	1.134	1.166	1.187	1.21	1.263	1.197	1.051					
6	2.404	2.09	2.193	2.28	2.467	2.248	2.158	2.173	2.233	2.278	2.317	2.418	2.289	2.016					
7	3.138	2.734	2.859	2.956	3.151	2.919	2.814	2.824	2.897	2.975	3.009	3.128	2.962	2.623					
8	3.695	3.233	3.37	3.468	3.665	3.425	3.311	3.322	3.406	3.502	3.521	3.673	3.462	3.089					
9	4.173	3.674	3.812	3.909	4.096	3.861	3.739	3.759	3.851	3.954	3.952	4.146	3.888	3.498					
10	4.595	4.074	4.208	4.298	4.482	4.248	4.119	4.157	4.253	4.351	4.327	4.575	4.261	3.867					
11	4.982	4.456	4.577	4.664	4.856	4.612	4.475	4.533	4.639	4.716	4.674	4.992	4.608	4.221					
12	5.353	4.836	4.941	5.023	5.239	4.971	4.825	4.908	5.025	5.072	5.013	5.407	4.949	4.579					
13	5.716	5.221	5.304	5.387	5.653	5.332	5.181	5.283	5.417	5.426	5.352	5.835	5.291	4.948					
14	6.075	5.617	5.675	5.773	6.133	5.698	5.549	5.662	5.831	5.786	5.703	6.303	5.643	5.335					
15	6.449	6.043	6.074	6.218	6.714	6.091	5.951	6.066	6.299	6.171	6.084	6.844	6.024	5.761					
16	6.86	6.52	6.523	6.753	7.486	6.535	6.414	6.517	6.847	6.608	6.521	7.554	6.459	6.253					
17	7.327	7.066	7.044	7.483	8.691	7.049	6.961	7.033	7.569	7.115	7.034	8.721	6.971	6.831					
18	7.941	7.767	7.733	8.683	10	7.728	7.681	7.716	8.731	7.785	7.72	10	7.662	7.588					
19	8.923	8.838	8.817	10	10	8.814	8.791	8.808	10	8.845	8.81	10	8.778	8.745					
20	10	10	10	10	10	10	10	10	10	10	10	10	10	10					

This conversion table enables the transformation of the raw total scores (calculated in the previous Table 3) into interval logit scores for each facet. The score for each trait can be obtained by summing the scores of the corresponding facets

and Open-Mindedness:  $r=0.71$ ,  $p<.001$ ), except the one between Negative Emotionality and Emotional Stability ( $r=-0.77$ ,  $p<.001$ ), which was large and negative.

## Discussion

The strengths of the BFI-2 (Soto & John, 2017) as a reliable and valid instrument to assess both personality traits and facets, as demonstrated by its large use and number of validations, can be further enhanced using RA (Bond et al., 2021).

After refining a preliminary Italian translation of the BFI-2 (Lee et al., 2020), we investigated its structure (aim 1) and supported the three-facet structure of each trait by means of CFA (confirming H1a). The reliability for each trait and facet was in line with the original instrument (Soto & John, 2017). MI analyses also indicated that the structure of the BFI-2, for each facet, resulted invariant at the scalar level across sex (confirming H1b). This is a preliminary step for investigating sex differences in the facets, given that scalar invariance is a prerequisite to comparing means across groups (Vandenberg & Lance, 2000). Therefore, potential sex differences detected with this instrument in future research, might be discussed as genuine differences between males and females' personality facets and not as caused by measurement artifacts.

We then checked, for each facet, the assumptions for applying the RA (about monotonicity, local independence, unidimensionality, and DIF; aim 2). In the cases in which some assumptions were violated (i.e., for 6 items violating monotonicity), we rescored the items and obtained that our data respected the requested parameters (confirming H2a). We could, therefore, apply the RA, and for each facet we found that our data fit the Rasch model well (confirming H2b). This allowed us to provide a conversion table to transform raw scores into interval logit scores, to be used for future research.

Finally, an analysis of correlations, based on the interval logit scores, allowed us to show the discriminant and convergent validity of the BFI-2-R (aim 3), at both the trait and facet-level for the first validity type, and at the trait-level for the second validity type (confirming H3a and H3b).

This study suffers from some limitations. First, we involved a sample of adults, without distinguishing different age groups. Further research should examine how the BFI-2-R functions with adults of different ages, and also with younger participants. Second, within the procedure for applying the RA, we found that some PSR indexes for the facets were quite low. This suggests being cautious when using this instrument for differentiating people along the same facet. In any case, the PSR for the traits were good,

indicating that the BFI-2-R logit scores, at the trait-level, can be reliably used to differentiate people within the trait. Moreover, the reliability for the facets, concerning the raw scores, was adequate. Third, only the BFI-10, derived from the BFI, was used to provide evidence of the convergent validity. Future studies should gather data about this type of validity using different instruments, also capturing the facet-level. Fourth, we collected self-report data, prone to desirability or memory biases. In the future, other-report data could help triangulate our findings.

Notwithstanding limitations, our work demonstrated the good psychometric properties of the Rasch version of the BFI-2, making available a version that gives the possibility to assess personality traits and facets benefitting from the advantages of the Rasch approach.

**Supplementary Information** The online version contains supplementary material available at <https://doi.org/10.1007/s12144-025-07584-7>.

**Author contributions** Roberto Burro: Conceptualization, Data Curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing original draft. Ivana Bianchi: Conceptualization, Methodology, Writing - review & editing. Daniela Raccanello: Conceptualization, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Writing - original draft.

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**Data availability** The study materials, data, and analysis scripts used for this article can be accessed at <https://doi.org/10.21227/7ae1-e859>.

## Declarations

**Ethics committee** The research was approved by the Ethic Committee of the Department of Human Sciences, University of Verona (protocol number: 635556).

**Competing interest** None.

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