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ORIGINAL PAPER

Continuous inclusion of other in the self

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Abstract
The Inclusion of Other in the Self (IOS) scale is a popular tool to measure interpersonal closeness that is increasingly being used in economics. We develop and validate a continuous version of the IOS scale. This Continuous IOS scale gives a finer measure and addresses the reluctance of subjects to report low scores on the standard IOS scale. We also propose a version of the standard IOS scale that meets its original design features. Our IOS scales are easy-to-use, well-documented, standardised, and available at https://github.com/geoffreycastillo/ios-js.

Keywords Social closeness · Social distance · Inclusion of other in the self · Connectedness

JEL Classification C91

1 Introduction

The Inclusion of Other in the Self (IOS) scale is one of the most popular measures of interpersonal closeness. It asks respondents to pick one of seven pairs of increasingly overlapping circles to indicate how close they feel toward another (Fig. 1a). Since its creation by Aron et al. (1992), the IOS scale has been repeatedly validated (Gächter et al., 2015) and widely adopted, with over 5000 citations on Google Scholar (see Aron et al., 2013; Branand et al., 2019, for reviews). In recent years it has spread to economics, for example to explain charitable donations (Goette

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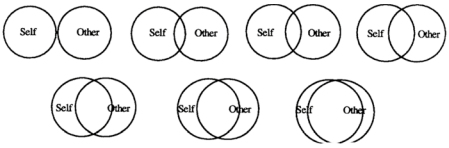
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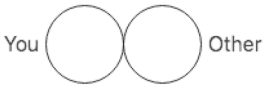
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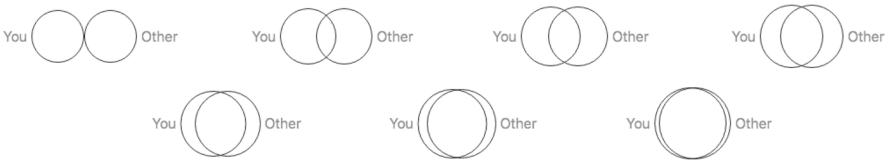
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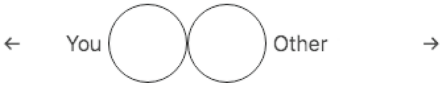
(a) Original IOS scale from Aron et al. (1992)



(b) Continuous IOS scale: click on the left circle and drag-and-drop it on the right



(c) Our implementation of the standard IOS scale



(d) Step-Choice IOS scale: click on the arrows to choose a pair of circles

Fig. 1 Four different IOS scales

& Tripodi, 2021), dictator game allocations (Robson, 2021), or team production (Gächter et al., 2023).

We offer a continuous version of the IOS scale (Fig. 1b) that allows a finer measurement of interpersonal closeness. In the Continuous IOS scale, respondents click the left circle (representing self) and drag-and-drop it on the right circle (representing the other) at the point of overlap that best represents their relationship with the other. Additionally, it allows a greater degree of overlap than the original IOS scale, and would thus be able to represent a higher perceived closeness.

Our Continuous IOS scale has the design features set out by Aron et al. (1992) in their seminal paper. We find, however, that most existing implementations of the standard IOS scale do not. We thus offer, in addition to the Continuous IOS scale, a re-implementation of the standard IOS scale that does (Fig. 1c). As a middle-ground, we also offer the Step-Choice IOS scale (Fig. 1d) which displays only one pair of circles with arrows on the left and right. Respondents are instructed to find the pair of circles which best represents their connection with the other by clicking on the arrows to move back and forth between the different

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pairs. The Step-Choice IOS scale thus retains the discreteness of the standard IOS scale but allows the use of more pairs of circles.

In an online experiment, we validate the Continuous IOS scale and the Step-Choice IOS scale against our implementation of the standard IOS scale. We find that the standard IOS scale elicits higher IOS scores than the Continuous IOS scale. This mainly comes from subjects who select a minimal overlap on both scales. Subjects must select the second pair of circles in the standard IOS scale to report minimal overlap, while they can report minimal overlap by choosing an overlap very close to zero in the Continuous IOS scale. Our results thus suggest that subjects might be reluctant to report the lowest IOS score on the standard IOS scale. The Continuous IOS scale addresses this by offering subjects the opportunity to report a low level of overlap without having to select an overlap as large as the one that corresponds to the second pair of circles in the standard IOS scale.

Our IOS scales can be implemented in any web-based experimental software, such as Qualtrics, oTree (Chen et al., 2016), or LIONESS (Giamattei et al., 2020). They are available as `ios.js` at https://github.com/geoffreycastillo/ios-js with full documentation. We also offer detailed instructions for Qualtrics and an example app for oTree.

Our scales offer various options. For all scales, the size of the circles can be customised. For the Step-Choice and standard IOS scales, users can select the number of circles. We also offer unbalanced versions of these scales with twice as many pairs of overlapping circles in the first half of the scale. This option would be useful, as we will see below, in cases where a majority of IOS scores are concentrated at the lower end of the scale.

Users can also customise the labels of the circles—'You' and 'Other' in Fig. 1. By doing so, our IOS scales can be directly translated into the Inclusion of Ingroup in the Self (IIS) scale (Tropp & Wright, 2001). The IIS scale is an extension of the IOS scale to groups obtained by replacing the 'Other' label attached to the right circle by the ingroup. The IIS allows one to measure the distance between an individual and a group or even between two groups.

In the next section following our discussion of the related literature, we describe how we construct our IOS scales to have the Aron et al. (1992) features. In Sect. 3 we present the experiment we designed to validate our Continuous and Step-Choice IOS scales. Section 4 presents the results and Sect. 5 concludes.

Related literature. Other continuous implementations of the IOS scale exist. However, they use circles with a fixed diameter and thus do not have the features highlighted by Aron et al. (1992). Further, they do not validate their continuous versions of the IOS scale in an experiment. For example, Le et al. (2007) offer a version that no longer works on modern browsers because the technology they relied on—Java applets—is deprecated. Kamphorst et al. (2017) ported this version to JavaScript, the technology we also rely on. More recently, Kinley and van Vugt (2023) offer a version for jsPsych (de Leeuw et al., 2023).

Further, Baader et al. (2024) propose expanding the original IOS scale to 11 circles—thus their extension is named IOS_{11}. They show that it outperforms the original, seven-circle IOS scale. Their extension introduces more circles in the first and

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in the final third of the scale. We have added an option to `ios.js` inspired by IOS_{11} that accomplishes this in the context of our scales.

As we hinted above, the IOS scale is becoming a popular tool in economics and has been used to show how social closeness impacts economic outcomes. For example, Goette and Tripodi (2021) find that social proximity as measured by the IOS scale drives social conformity, which influences how much money people give to an NGO. Hofmann et al. (2021) show that the presence of close others, as measured by the IOS scale, increases voluntary payments in a Pay-What-You-Want context. Dimant (2024) studies political polarisation and distinguishes between ingroup love and outgroup hate thanks in part to the IOS scale. Gächter et al. (2023) show that group cohesion, measured with an oneness scale that includes the IOS scale, increases team production as captured by a weak-link coordination game. We ourselves have already used the Continuous IOS scale and `ios.js` in a series of large online experiments to study social discounting (Beranek & Castillo, 2024).

Further, in a lab-in-the-field experiment in Uganda, Robson (2021) uses the IOS scale to show that social connectedness enters the utility function and affects decisions in a modified dictator game. Castillo (2021) uses the IOS scale to show how preferences defined over social distance depend on the task used to elicit them—a translation of the classical preference reversal phenomenon to the social domain. In both Robson (2021) and Castillo (2021), about half of the respondents report the same IOS scores for the two recipients they face. The finer measurement brought by the Continuous IOS scale would help in those cases where the different others evaluated by respondents are too similar to be discriminated by the original IOS scale.

2 Constructing the IOS scale

When creating the figures for the IOS scale, the two design features highlighted by Aron et al. (1992) were that: "(a) the total area of each figure is constant (thus as the overlap of the circles increases, so does the diameter), and (b) the degree of overlap progresses linearly, creating a seven-step, interval-level scale". Feature (a) means that circle diameters increase as the distance between the circles decreases to keep constant the total area of self plus other. This feature ensures that no sense of self or other is lost when overlap increases, which aligns with Aron and Aron's (1986) conception of relationships. Feature (b) ensures there are no jumps between any two pairs of circles, a necessary condition to generate a valid, linear, one-to-seven measure. Otherwise, some increases in overlap would be larger than others which might give rise to threshold effects.

We show on Table 1, however, that the original figures in Aron et al. (1992) do not have these features. That is the case for most, if not all, of the literature that followed which used either directly the Aron et al. (1992) figures, their own figures, or a series of overlapping circles with non-increasing diameters.

Finding a series of overlapping circles that have both of these features is a non-trivial problem without a closed-form solution. We rely on simulations (see Appendix A for details) to find, for every proportion of overlap, a corresponding circle

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Table 1 Total area and change in the overlap of IOS scales

Pair	Aron et al. (1992)		Ours	
	Total area	Change % overlap	Total area	Change % overlap
1	157.08		157.08	
2	152.75	7.32	157.03	14.32
3	151.65	3.53	157.12	14.24
4	153.31	11.00	157.02	14.30
5	150.00	13.75	157.22	14.25
6	148.76	9.55	157.03	14.30
7	149.93	19.69	157.08	14.37

Starting diameter normalised to 10

'Change % overlap' does not sum to 100% because the last pair of circles does not represent full overlap (see Appendix A)

diameter. These calculations allow us to create an IOS scale that has the features highlighted by Aron et al. (1992). We use these calculations to construct our version of the standard IOS scale as well as our new Step-Choice and Continuous IOS scales, which we test in the following experiment.

3 Experimental design

In our experiment, we test whether respondents choose the same overlap regardless of the version of our IOS scales they use. More specifically, within-subjects respondents indicate how close they feel toward another using our standard IOS scale and either our Continuous or our Step-Choice IOS scales. The order of the IOS scales is randomised between-subjects. We add a filler task between the IOS scales: we ask subjects to solve 10 mathematics problems involving the addition and subtraction of three-digit numbers under time pressure.

As highlighted by Kinley and van Vugt (2023), a difference between the standard IOS scale and IOS scales that show only one pair of circles at a time—such as our Continuous and Step-Choice IOS scales—is that in the latter subjects are presented with an initial "default" degree of overlap as opposed to seeing all possible degrees of overlap. For this reason, we require subjects to manipulate the IOS scale from no overlap to full overlap before they can proceed to the task itself (see Figs. 11 and 13 of the instructions in Appendix B). This also ensures our JavaScript code works as intended on subjects' browsers; if it did not, subjects could not proceed beyond this intentional point of failure.

In contrast to most of the literature, we use real people as the target of the IOS scales as opposed to hypothetical 'others'. To do so, we first surveyed members of the US general public on MTurk forming a diverse pool of potential targets. We asked them a number of questions, mostly standard demographic questions as well as some questions about their opinions on various social issues (see Supplementary material for a list of questions used). Thereafter, we invited the subjects for the

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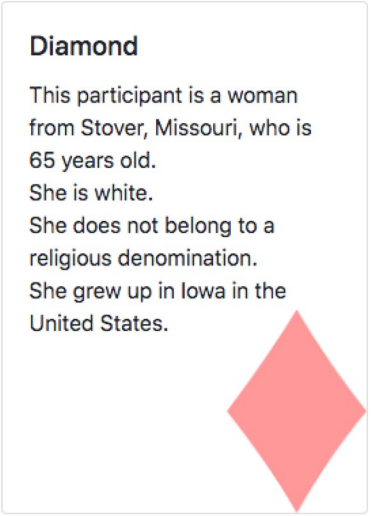


Fig. 2 Card display used in the experiment

experiment reported here and asked them the same questions. We paired them with a target drawn at random from the pool of the originally surveyed participants.

We present the target—the 'other' participant in the IOS scale—using the card display shown in Fig. 2. The card suit (♣♦♠♥) is assigned randomly to the target and used to refer to them throughout the experiment. To make sure subjects engage with their assigned target, we ask them to write the first things that come to their mind when they read the card in at least 25 characters.

The advantage of this procedure is that we can assess whether the IOS score decreases with the demographic dissimilarity between subjects and their target. We can also assess how subjects' characteristics influence the IOS scores they report.

The experiment took place in November 2020. A session lasted about 13 min and the average payment was $1.43. The payment was composed of a fixed $0.50 participation fee and $0.10 for each mathematics problem correctly solved. We analyse below the choices of 644 participants: 328 who evaluate their target using the standard and the Continuous IOS scales and 316 who use the standard and the Step-Choice IOS scales.[1] Full instructions for the tasks used in the experiment can be found in Appendix B.

[1] In total 998 people participated in our experiment. We removed 96 obvious bots who for example copied-and-pasted the instruction text or random text found online. We also removed 257 participants who gave at least two suspicious answers; for example, stating a ZIP code too far from the location inferred from the IP address or reporting being less than 12 years old or greater than 75 years old when they had their first child. All of these exclusion criteria were pre-registered. We also excluded a subject who managed to report a proportion of overlap greater than 1 in the Continuous IOS scale. Our results are similar when we include all 998 participants regardless of whether they satisfy our exclusion criteria.

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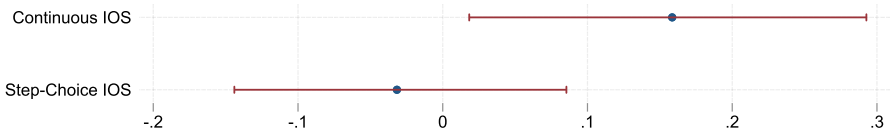


Fig. 3 Average difference between the IOS scores reported with the standard IOS scale and the Continuous or the Step-Choice IOS scale (with bootstrapped 95% confidence intervals)

4 Results

4.1 Comparing the Continuous and Step-Choice IOS scales to the standard IOS scale

We consider our new IOS scales—Step-Choice IOS scale, Continuous IOS scale—to be validated against our implementation of the standard IOS scale if there is no difference between the scores reported by subjects when they use the new IOS scale or the standard IOS scale. The scores generated by the standard IOS scale and the Step-Choice IOS scale are discrete variables ranging from one (representing no overlap) to seven (representing substantial overlap). In contrast, the score generated by the Continuous IOS scale is a continuous variable ranging between zero and one. To allow comparison, we first convert the overlap given by the Continuous IOS scale into a one-to-seven measure.[2] We then subtract the score obtained with the new IOS scale from the score obtained with the standard IOS scale. A positive difference means that subjects reported a higher IOS score when using the standard IOS scale.

In Fig. 3, we plot the average of this difference. We start by comparing the Continuous IOS scale to the standard IOS scale in the top part of the Figure. We see that the standard IOS scale leads to higher IOS scores than the Continuous IOS scale: the difference is small but positive and significant (Wilcoxon matched-pairs signed-ranks test, $z = 4.943$ and $p < 0.001$).[3] Therefore, we reject the null hypothesis that subjects report the same IOS score on both scales. Hence our first result:

[2] We convert the proportion of overlap x with the thresholds: 1: $0 \leq x < 0.0711687543$; 2: $0.0711687543 \leq x < 0.2144646286$; 3: $0.2144646286 \leq x < 0.3594493146$; 4: $0.3594493146 \leq x < 0.5017821132$; 5: $0.5017821132 \leq x < 0.6441712323$; 6: $0.6441712323 \leq x < 0.7889021411$; 7: $0.7889021411 \leq x \leq 1$. To generate the thresholds, we took the proportions of overlaps that correspond to each pair of circles in the standard IOS scale, then divided equally the space around them. The thresholds were pre-registered.

[3] We confirm this with Somers' $D = 0.278$, with a 95% confidence interval [0.089, 0.466].

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Result 1 The standard IOS scale elicits higher scores than the Continuous IOS scale.

The bottom part of Fig. 3 compares the standard IOS scale to the Step-Choice IOS scale. As can be seen, there is no difference between these two scales: the difference is not statistically different from 0 (Wilcoxon matched-pairs signed-ranks test, $z = -0.810$ and $p = 0.4135$).[4] Therefore, we cannot reject the null hypothesis that subjects report the same IOS score on both scales. Hence our second result:

Result 2 We do not detect a difference between the scores elicited from the standard IOS scale and the Step-Choice IOS scale.

4.2 Why does the standard IOS scale result in higher IOS scores than the Continuous IOS scale?

To better understand why the standard IOS scale yields higher IOS scores compared to the Continuous IOS scale, Fig. 4 displays the IOS score reported with the Continuous IOS scale as a function of the IOS score reported with the standard IOS scale. Each dot represents a subject. There are two notables features. First, Continuous IOS scores are dispersed around their corresponding standard IOS scores. Second, when considering a specific standard IOS score, the Continuous IOS scores tend to skew towards lower values.[5]

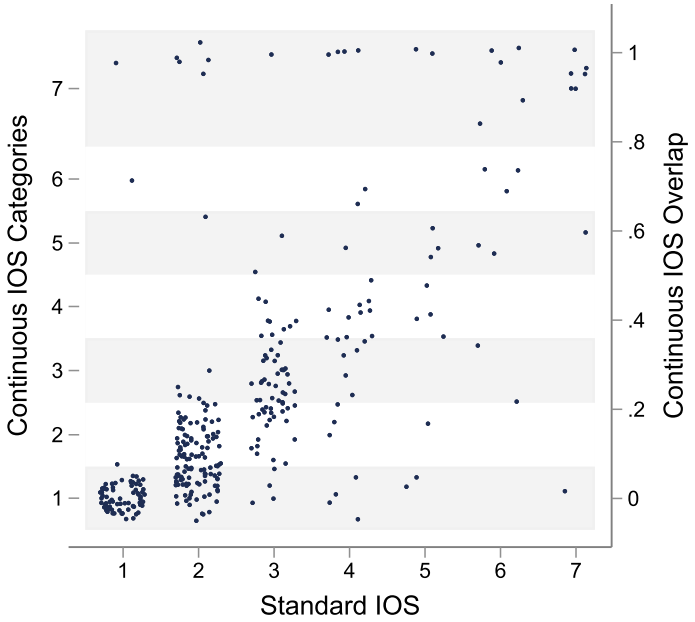
The dispersion can be explained by random errors resulting from asking subjects to report the IOS score twice in a row. Continuous IOS scores are mostly the same as the corresponding standard IOS scores or in the adjacent categories. For example, 25 of the 66 subjects (37.88%) who report a standard IOS score of 3 report the exact same score on the Continuous IOS scale. An additional 36 subjects report scores in the categories adjacent, with 25 subjects (37.88%) reporting a score of 2, and 11 subjects (16.67%), a score of 4. Only 5 subjects (7.58%) report scores beyond the adjacent categories. (See Appendix C for the detailed frequency tables.)[6]

[4] We also confirm this with Somers' $D = 0.063$, with a 95% confidence interval $[-0.124, 0.251]$.

[5] Also notable is the fact that a number of subjects, who reported a standard IOS score between 1 and 6, report a Continuous IOS score of 7 irrespectively. They represent, however, only 18 subjects out of the 328 in this treatment (about 5.49%). We observe the same phenomenon in the Step-Choice IOS scale, albeit less pronounced (9 out of 316 subjects, 2.85%). We attribute this to a combination of inattention to the IOS task at hand and to the text on the IOS scale task instructions page before where we asked subjects to change the circles so that they are overlapping as much as possible to go to the next page. It is possible that a few inattentive subjects mistook the actual task as an additional attention check and thought they had to report as much overlap as possible in the task itself to go to the next page.

[6] Step-Choice IOS scores are also dispersed around their corresponding standard IOS scores, but less so than Continuous IOS scores. This is perhaps not surprising given that, with the standard and the Step-Choice IOS scales, subjects can simply count the number of circles starting from no-overlap to choose the same pair of circles twice.

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The left y axis shows the Continuous IOS scale in seven categories while the right y axis shows the Continuous IOS scale between 0 and 1. Shown with jitter of 6 to differentiate between data points.

Fig. 4 Relation between the IOS scores reported with the standard IOS scale and those reported with the Continuous IOS scale

The skew of the Continuous IOS scores towards lower values is the reason the average difference in Fig. 3—standard IOS score minus Continuous IOS score—is positive. It is particularly apparent in Fig. 4 by focusing on subjects who report a Continuous IOS score of 1: many of these subjects report a standard IOS score of 2. In fact, when we remove these 54 subjects, the average difference between standard and Continuous IOS scale is no longer significant (Wilcoxon matched-pairs signed-ranks test, $z = 1.018$ and $p = 0.3095$).

This pattern could be explained by the reluctance of subjects to report the lowest IOS score with the standard IOS scale. In the standard IOS scale, subjects who want to report some connection with their match, at least more connection than no overlap would imply, are forced to pick the second pair of circles. On the other hand, the Continuous IOS scale allows them to report at least some overlap; while at the same time, this overlap falls short of an overlap corresponding to an IOS score of 2. As would be predicted by this explanation, we observe some bunching below the threshold that corresponds to an IOS score of 2.

The fact that subjects avoid reporting an IOS score of 1 with the standard IOS scale could also be a manifestation of the compromise effect (see, for example, Beauchamp et al., 2020, in the context of risk preference elicitation). According to the compromise effect, people want to avoid extremes and prefer to choose options that are more in the middle. In the standard IOS scale, avoiding the low extreme

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means reporting an IOS score of 2. In the Continuous IOS scale, avoiding the low extreme means reporting a small degree of overlap that might not correspond to an IOS score of 2.

To mitigate this issue in the standard IOS scale, we propose adding intermediate pairs of overlapping circles in-between the first half of the circles to create an unbalanced, standard or Step-Choice IOS scale. This addition would give subjects more opportunity to report small levels of overlap. For example, the unbalanced version of the standard IOS scale now has 10 pairs of overlapping circles: the original 7 with extra pairs of overlapping circles between 1 and 2, between 2 and 3, and between 3 and 4. We have implemented this option in `ios.js`.

4.3 The effect of demographic dissimilarity and of demographic characteristics on IOS scores

We conclude with a number of exploratory, non-pre-registered analyses. We focus on the standard IOS scale since we have the most observations for this scale. We first look at how demographic dissimilarity between a subject and their target influence the IOS score they report. For us, demographic dissimilarity measures the proportion of discordant responses given to the questions displayed on the card shown in Fig. 2. A dissimilarity of 0 refers to a subject who answers exactly as their target to those questions, and a dissimilarity of 1, to a subject who answers as differently as possible.

Model (1) in Table 2 reports the result of the corresponding ordered logistic regression. We find that, as dissimilarity increases, interpersonal closeness as indicated by the IOS score decreases. Therefore, the IOS scale captures something tangible and measurable.

Then, in models (2) and (3) in Table 2, we look at how a subject's own demographic characteristics influence the IOS score they report. We find that those who do part-time work, who have only completed 12th grade without a degree or less, or who support a political party different from the main parties, report lower IOS scores. This finding suggests that one needs a minimal level of stability to start feeling connected to others. Further, people who think others are trustworthy and people who belong to a labour union report higher IOS scores. The results are unchanged if we leave dissimilarity out (in model 2) or include it (in model 3).[7]

Some associations are more difficult to interpret: for example, people who approve of sex before marriage report lower IOS scores. Others should be interpreted with care: for example, people who report their race as Chinese or Korean report lower IOS scores. However, there are not many people in our sample who reported their race as Chinese or Korean and, consequently, they are less likely to be matched with someone who reported the same race.

[7] Subjects' own demographic characteristics enter the computation of demographic dissimilarity. Therefore, one might be worried about collinearity. As we show in Table 2, the results are the same regardless of whether we leave dissimilarity out (in model 2) or include it (in model 3). Further, the VIF also indicates the absence of collinearity with no value above 3.03.

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Table 2 How dissimilarity and respondents' characteristics explain the reported IOS score, ordered logistic regression

Dependent variable: IOS score	Coef. (SE)		
	(1)	(2)	(3)
Dissimilarity	– 1.838*** (0.521)		– 2.264*** (0.595)
Age		– 0.004 (0.008)	0.000 (0.008)
Gender (ref.: Female)			
Male		0.333** (0.165)	0.319* (0.165)
Race (ref.: White)			
Asian Indian		0.137 (0.525)	0.388 (0.536)
Black		0.309 (0.362)	0.510 (0.361)
Chinese		– 1.016*** (0.390)	– 0.981** (0.381)
Korean		– 1.645** (0.768)	– 1.466* (0.769)
Other		0.091 (0.364)	0.355 (0.362)
Ethnicity (ref.: None)			
Mexican		– 0.204 (0.393)	0.149 (0.429)
Other		– 0.779 (0.556)	– 0.408 (0.572)
Religion (ref.: None)			
Jewish		0.256 (0.566)	0.356 (0.578)
Other		– 0.585 (0.383)	– 0.409 (0.382)
Protestant		– 0.583** (0.264)	– 0.487* (0.263)
Roman Catholic		0.390* (0.226)	0.493** (0.230)
Political party (ref.: Democrat)			
Independent		0.070 (0.194)	0.025 (0.194)
No preference		– 0.479 (0.419)	– 0.356 (0.448)
Other party		– 0.975** (0.487)	– 1.001* (0.522)
Republican		0.382 (0.254)	0.367 (0.252)

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Table 2 (continued)

Dependent variable: IOS score	Coef. (SE)		
	(1)	(2)	(3)
Marital status (ref.: Married)			
Divorced		– 0.554** (0.319)	– 0.528 (0.323)
Never		– 0.283 (0.205)	– 0.244 (0.205)
Separated or widowed		0.870* (0.446)	0.879* (0.451)
Social class (ref.: Middle class)			
Lower class		0.001 (0.301)	– 0.095 (0.295)
Upper class		0.317 (0.469)	0.237 (0.473)
Working class		0.079 (0.184)	0.029 (0.186)
Work last week (ref.: Full time work)			
Housework		– 0.237 (0.209)	– 0.250 (0.208)
Part time work		– 0.565** (0.254)	– 0.547** (0.258)
School		– 0.127 (0.426)	– 0.038 (0.458)
Place growing up (ref.: Small town)			
Farm		0.172 (0.434)	0.099 (0.422)
Large city		0.071 (0.262)	0.099 (0.261)
Medium city		0.142 (0.212)	0.096 (0.215)
Open country		– 0.225 (0.343)	– 0.313 (0.349)
Suburb		0.039 (0.224)	– 0.027 (0.228)
Highest degree (ref.:College or some college)			
12th grade no degree and less		– 1.099** (0.540)	– 1.024* (0.556)
Beyond bachelors		0.207 (0.214)	0.183 (0.212)
High school graduate		– 0.052 (0.271)	– 0.060 (0.266)
Number of children		0.063 (0.047)	0.066 (0.046)

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Table 2 (continued)

Dependent variable: IOS score	Coef. (SE)		
	(1)	(2)	(3)
Household income		– 0.616 (0.451)	– 0.610 (0.449)
People are helpful		0.154 (0.230)	0.154 (0.228)
People try to take advantage of you		0.255 (0.249)	0.154 (0.228)
People are trustworthy		0.717*** (0.229)	0.716*** (0.224)
Belong to labour union		0.789*** (0.304)	0.797** (0.311)
Unemployed in the past 10 years		– 0.112 (0.171)	– 0.084 (0.173)
Support affirmative action		0.516 (0.292)	0.465 (0.296)
Approve sex before marriage		– 0.957*** (0.360)	– 1.000*** (0.358)
Approve same-sex relations		0.011 (0.347)	0.046 (0.348)
Approve death penalty		0.278 (0.172)	0.225 (0.174)
cut1	– 1.845*** (0.204)	– 1.733** (0.701)	– 2.384*** (0.711)
cut2	– 0.097 (0.190)	0.286 (0.698)	– 0.331 (0.706)
cut3	0.774*** (0.190)	1.310* (0.702)	0.705 (0.708)
cut4	1.505*** (0.198)	2.161*** (0.702)	1.565** (0.707)
cut5	2.100*** (0.214)	2.834*** (0.707)	2.241*** (0.712)
cut6	2.992*** (0.281)	3.808*** (0.728)	3.213*** (0.731)
Observations	644	644	644
Pseudo R^2	0.006	0.081	0.088
Wald χ^2	12.437	160.775	162.343
Prob > χ^2	0.000	0.000	0.000

Robust standard errors. *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$

5 Conclusion

In summary, we offer a new implementation of the standard IOS scale that has the features highlighted by Aron et al. (1992). We also offer a new version of the IOS scale—the Continuous IOS scale—that allows for the selection of any degree of overlap. As an intermediary, we propose the Step-Choice IOS scale. We validate our new IOS scales in an experiment, where we find that the standard IOS scale results in higher IOS scores than the Continuous IOS scale. We interpret this difference as a reluctance of some subjects to select the lowest IOS score corresponding to no overlap in the standard IOS scale. We also find that IOS scores decrease with demographic dissimilarity between subject and target.

Appendices

Appendix A: Formulas to generate the IOS scale

Following Aron et al. (1992), the IOS has two requirements:

1. The total area of each pair of overlapping circles should stay constant; and
2. The degree of overlap should increase linearly between each pair.

Let r be the radius of the circles and d the distance between them measured centre-to-centre. Before any overlap occurs, the total area is the area of the two circles:

$$A_C(r) = 2\pi r^2.$$

As the circles start to overlap, however, using this formula would result in counting the overlap area twice. We thus need to compute the overlapping area[8]

$$A_O(r,d) = 2r^2\cos^{-1}\left(\frac{d}{2r}\right) - \frac{1}{2}d\sqrt{4r^2 - d^2}$$

and remove it once from the total area, giving us the area

$$A_T(r,d) = A_C(r) - A_O(r,d) = 2\pi r^2 - 2r^2\cos^{-1}\left(\frac{d}{2r}\right) + \frac{1}{2}d\sqrt{4r^2 - d^2}.$$

Denote by r_0 the starting radius, when there is no overlap. Using these formulas, we can translate the first requirement as: for all r and d, it must be that

$$A_T(r,d) = A_C(r_0);$$

and the second requirement as: the ratio

[8] https://mathworld.wolfram.com/Circle-CircleIntersection.html, accessed 17/02/2022.

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Table 3 Estimates from the polynomial fitted to the simulated values

β_0	1.41450×10^{3}*** (1.39585×10^{-1})
β_1	-6.42812×10^{-1}*** (2.14726×10^{-3})
β_2	1.78871×10^{-4}*** (9.48586×10^{-6})
β_3	2.05904×10^{-8} ($1.52208 \times ^{-8}$)
β_4	6.93823×10^{-11}*** (7.96705×10^{-12})
R^2	9.99991×10^{-1}
Observations	101

***$p < 0.001$; **$p < 0.01$; *$p < 0.05$

$$\frac{A_O(r,d)}{A_T(r,d)}$$

should increase linearly as the distance d decreases.

To find a solution to the problem,[9] we applied the following algorithm:

- Fix the initial radius r_0, $d = 2r_0$, and compute the initial area $A_C(r_0)$
- Generate all (r, d) such that $r_0 < r < 2r_0$ and $0 < d < 2r_0$
- For each (r, d), compute $A_O(r, d)$, $A_T(r, d)$ and $\frac{A_O(r,d)}{A_T(r,d)}$
- Remove any (r, d) such that $A_T(r, d)$ is not within 0.1% of $A_C(r_0)$
- If we want n pairs of overlapping circles, for each target proportion of overlap $\tau \in \left\{0, \frac{1}{n}, \frac{2}{n}, \ldots, 1\right\}$, pick the (r, d) that result in the closest $\frac{A_O(r,d)}{A_T(r,d)}$ to τ.

Therefore, we find suitable (r, d) for any number of circles n. Note that, in the IOS scale, the last pair of circles does not represent full overlap. Therefore, to find an IOS scale with n pairs of circles, we do it as if we were generating $n + 1$ pairs of circles and then ignore the last one. For this reason, the overlaps we target are $\left\{0, \frac{1}{n}, \frac{2}{n}, \ldots, 1\right\}$ and not $\left\{0, \frac{1}{n-1}, \frac{2}{n-1}, \ldots, 1\right\}$. Table 1 in the main text compares our values to Aron et al. (1992) for $r_0 = 5$ and $n = 7$.

To create the Continuous IOS scale, we repeat the above steps with $n = 100$, then fit a polynomial

$$2\hat{r} = \sum_{i=0}^{m} \beta_i d^i + \epsilon$$

on the generated data. We stop at $m = 4$ since a greater m does not improve fit. Table 3 shows the estimates. In our JavaScript widget, we use all the decimals we get from the estimation.

The code of the simulation is available at https://doi.org/10.5281/zenodo.11913700.

[9] We thank Christopher Hammond and Yan Zhuang from Connecticut College who helped us try finding a closed-form solution before we turned to simulations.

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Appendix B: Tasks used in the experiment

First, subjects complete a forty question survey. Appendix B contains a full list of the questions from the survey.

Second is the presentation of the target. As described in Sect. 3 of the main text, the survey that subjects in this experiment completed was the same survey that a pool of previously surveyed participants completed. We randomly pair each subject in this experiment with a target from the previous subject pool. We introduce the target to the subject by revealing the target's answers to several of the survey questions. Figure 5 shows how we present the target's answers to the selected survey questions on a card.

Third, subjects complete a target familiarization task where they write the first things that come to mind about the target in at least 50 characters. This functions, to some extent, as an attention check for the subjects to ensure subjects read closely the information on the card. Our evaluation of their responses is one means by which we identify bots. The instructions for this target familiarisation task are shown in Fig. 6.

Fourth, subjects complete our version of the standard IOS scale task. The instructions for the standard IOS scale task are shown in Fig. 7. The standard IOS scale task itself is shown in Fig. 8.

Fifth, subjects complete a filler task where they add or subtract two three-digit numbers. This is the only experimental task that is financially incentivised; subjects receive \$0.10 for each correctly solved problem. We implement this filler task so that subjects do not complete the two IOS tasks back to back. The instructions for the filler task are shown in Fig. 9. The filler task itself is shown in Fig. 10.

Sixth, subjects complete either the Step-Choice IOS task or the Continuous IOS task. To advance from the instruction screen to the task itself, we require subjects to manipulate each scale such that the circles overlap as much as possible. This functions as an attention check for the subjects and forces them to recognise the full extent of possible overlap. The instructions for the Step-Choice IOS scale task are shown in Fig. 11. The Step-Choice IOS scale task itself is shown in Fig. 12. The instructions for the Continuous IOS scale task are shown in Fig. 13. The Continuous IOS scale task itself is shown in Fig. 14.

All subjects completed two IOS tasks: the standard IOS scale task and one of either the Continuous IOS scale task or the Step-Choice IOS scale task. The order in which they participate the IOS tasks is randomised between subjects.

Demo versions of our IOS scales are available at https://geoffreycastillo.com/ios-js-demo/.

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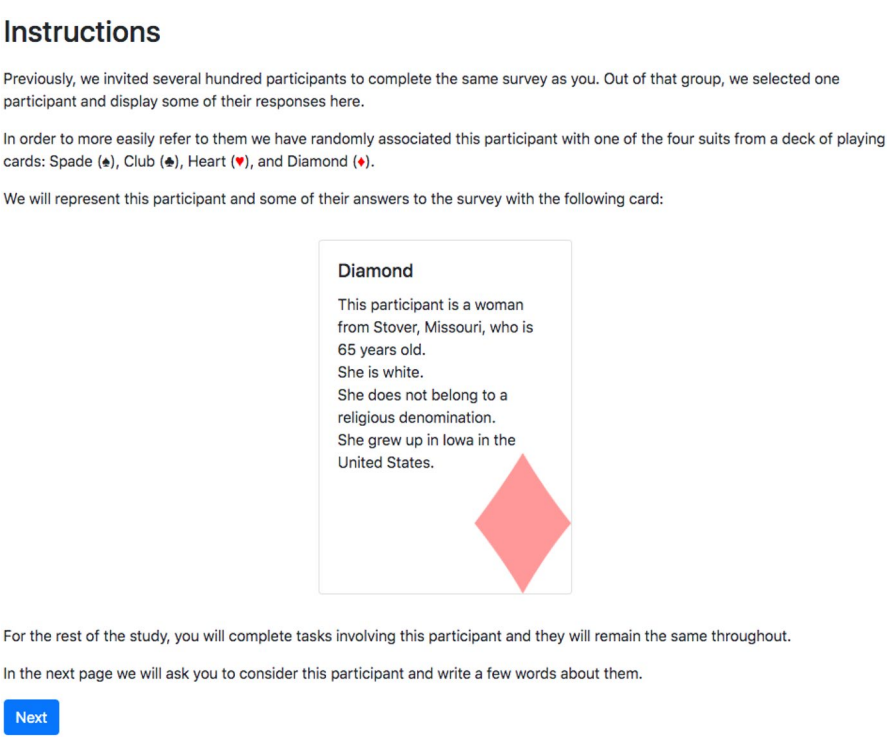


Fig. 5 Presentation of the target

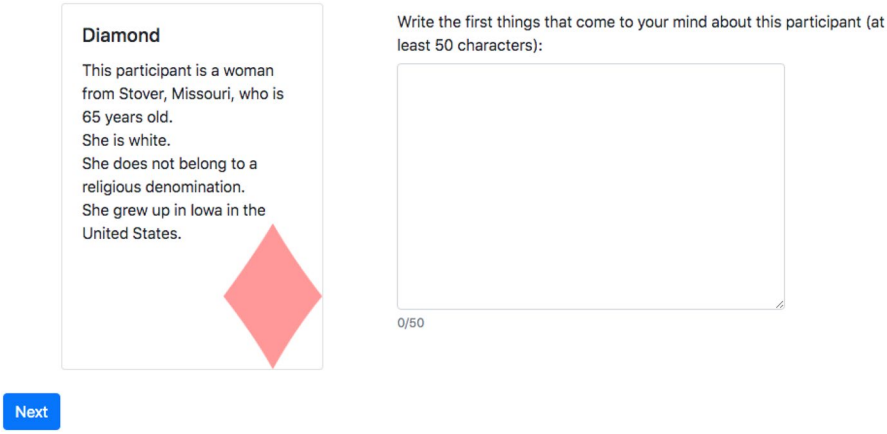


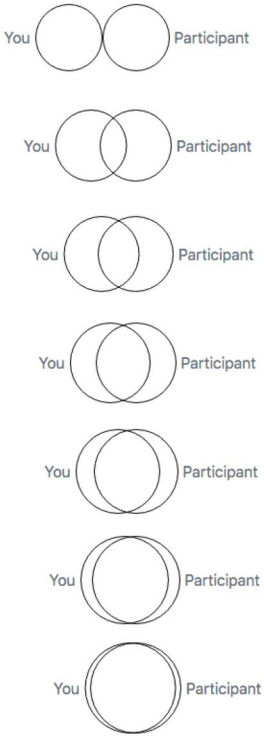
Fig. 6 Target familiarisation task

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Instructions

We will now ask you to consider how connected you feel towards the participant.

More specifically, we will show you the following circles:



The overlap of the circles represents the connection you feel towards the other participant. For example, a stronger connection between you and the other participant would be represented by a greater overlap of the circles.

We will ask you to select a pair of circles that best represents the connection you feel toward the participant whose survey responses you just read.

You can practice on this page as much as you want.

Click the 'Next' button when you're ready.

Next

Fig. 7 Standard IOS scale task instructions

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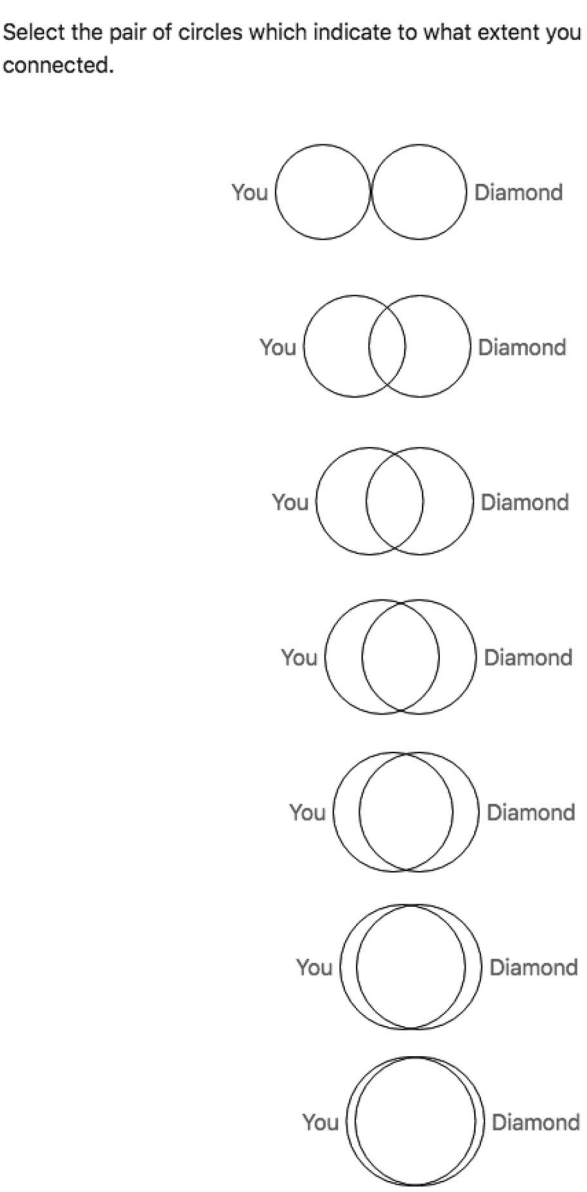


Fig. 8 Standard IOS scale task

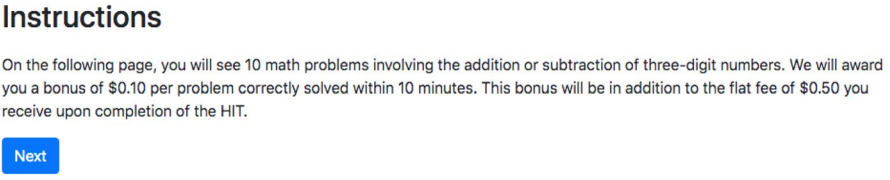


Fig. 9 Filler task instructions

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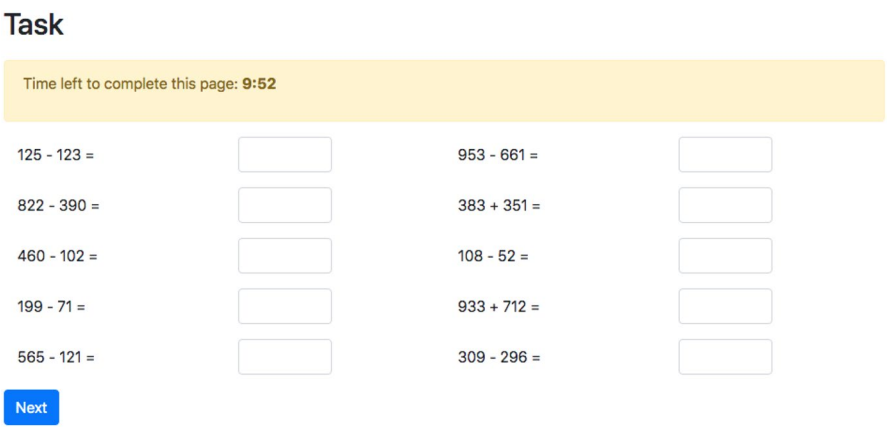


Fig. 10 Filler task

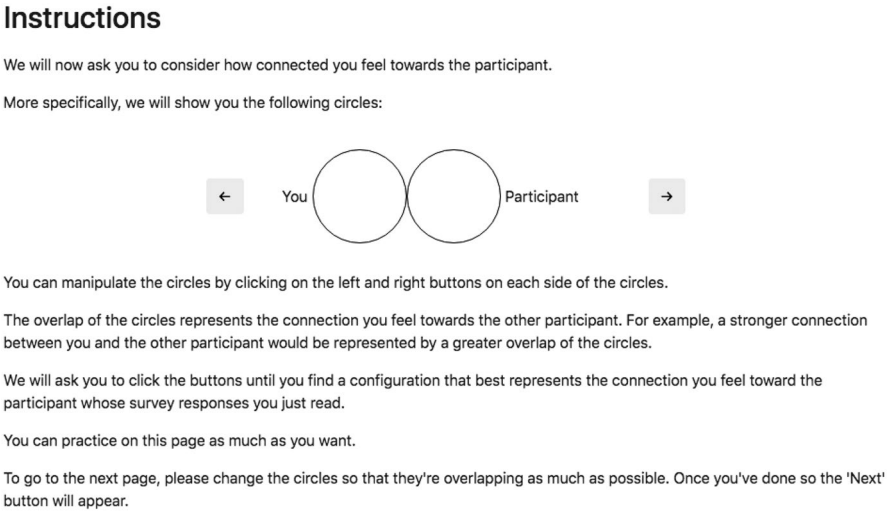


Fig. 11 Step-Choice IOS task instructions

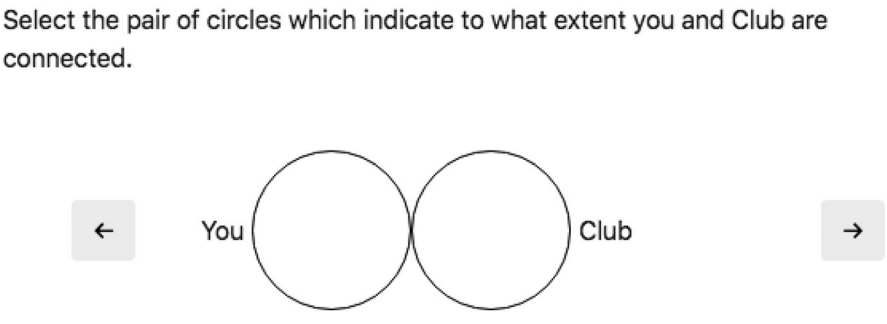


Fig. 12 Step-Choice IOS task

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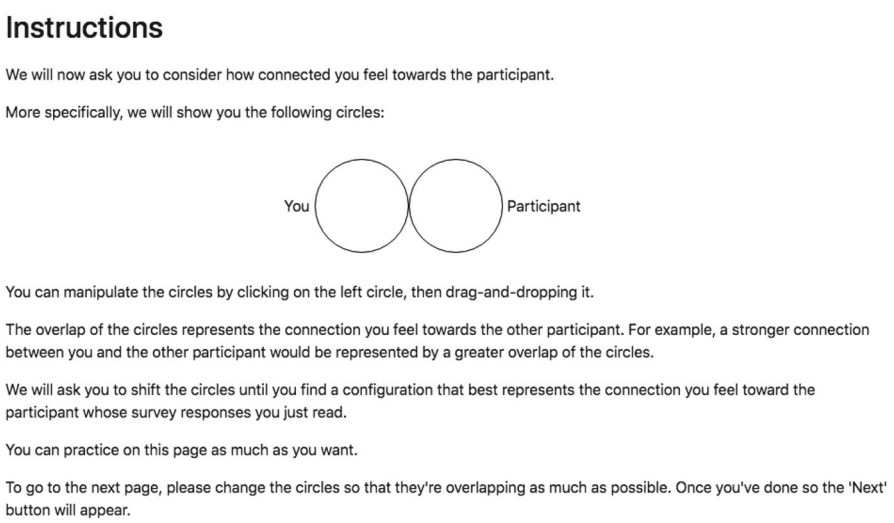


Fig. 13 Continuous IOS scale task instructions

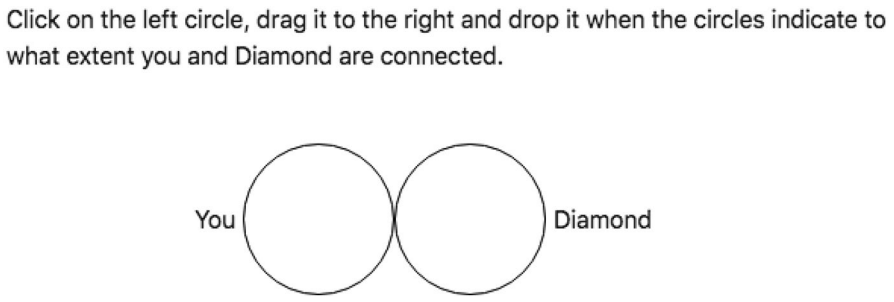


Fig. 14 Continuous IOS task

Appendix C: Frequency tables

Table 4 shows the number of subjects who reported each Continuous IOS score as a function of their chosen standard IOS score. It also shows:

- The row percentage: the percentage of subjects who chose a Continuous IOS score for a given standard IOS score;
- The column percentage: the percentage of subjects who chose a standard IOS score for a given Continuous IOS score; and finally,
- The cell percentage: the percentage of subjects overall who chose a particular combination of standard and Continuous IOS score.

Table 5 provides the same information for the Step-Choice IOS score.

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Table 4 Number of subjects, row %, column % and cell % for all combinations of standard IOS score and Continuous IOS score (converted from the proportion of overlap)

Standard	Continuous							
	1	2	3	4	5	6	7	Total
1	**71**	1	0	0	0	1	1	74
	95.95	1.35	0.00	0.00	0.00	1.35	1.35	100.00
	52.59	1.10	0.00	0.00	0.00	20.00	4.17	22.56
	21.65	0.30	0.00	0.00	0.00	0.30	0.30	22.56
2	54	**61**	5	0	1	0	5	126
	42.86	**48.41**	3.97	0.00	0.79	0.00	3.97	100.00
	40.00	**67.03**	13.16	0.00	9.09	0.00	20.83	38.41
	16.46	**18.60**	1.52	0.00	0.30	0.00	1.52	38.41
3	3	25	**25**	11	1	0	1	66
	4.55	37.88	**37.88**	16.67	1.52	0.00	1.52	100.00
	2.22	27.47	**65.79**	45.83	9.09	0.00	4.17	20.12
	0.91	7.62	**7.62**	3.35	0.30	0.00	0.30	20.12
4	4	3	5	**11**	2	1	4	30
	13.33	10.00	16.67	**36.67**	6.67	3.33	13.33	100.00
	2.96	3.30	13.16	**45.83**	18.18	20.00	16.67	9.15
	1.22	0.91	1.52	**3.35**	0.61	0.30	1.22	9.15
5	2	1	1	2	**4**	0	2	12
	16.67	8.33	8.33	16.67	**33.33**	0.00	16.67	100.00
	1.48	1.10	2.63	8.33	**36.36**	0.00	8.33	3.66
	0.61	0.30	0.30	0.61	**1.22**	0.00	0.61	3.66
6	0	0	2	0	2	**3**	5	12
	0.00	0.00	16.67	0.00	16.67	**25.00**	41.67	100.00
	0.00	0.00	5.26	0.00	18.18	**60.00**	20.83	3.66
	0.00	0.00	0.61	0.00	0.61	**0.91**	1.52	3.66
7	1	0	0	0	1	0	**6**	8
	12.50	0.00	0.00	0.00	12.50	0.00	**75.00**	100.00
	0.74	0.00	0.00	0.00	9.09	0.00	**25.00**	2.44
	0.30	0.00	0.00	0.00	0.30	0.00	**1.83**	2.44
Total	135	91	38	24	11	5	24	328
	41.16	27.74	11.59	7.32	3.35	1.52	7.32	100.00
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
	41.16	27.74	11.59	7.32	3.35	1.52	7.32	100.00

Example: Looking at the first cell, 71 subjects reported a standard IOS score of 1 and a Continuous IOS score of 1. They represent 95.95% of the 74 subjects who reported a standard IOS score of 1 and 52.59% of the 135 subjects who reported a Continuous IOS score of 1. They also represent 21.65% of the 328 overall subjects

Bold indicates the diagonal where standard and Continuous IOS scores are equal one to another

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Table 5 Number of subjects, row %, column % and cell % for all combinations of standard IOS score and Step-Choice IOS score

Standard	Step-Choice							
	1	2	3	4	5	6	7	Total
1	**67**	9	0	0	1	0	0	77
	87.01	11.69	0.00	0.00	1.30	0.00	0.00	100.00
	89.33	6.87	0.00	0.00	6.67	0.00	0.00	24.37
	21.20	2.85	0.00	0.00	0.32	0.00	0.00	24.37
2	4	**115**	6	2	0	1	1	129
	3.10	**89.15**	4.65	1.55	0.00	0.78	0.78	100.00
	5.33	**87.79**	13.04	8.00	0.00	9.09	7.69	40.82
	1.27	**36.39**	1.90	0.63	0.00	0.32	0.32	40.82
3	0	6	**29**	6	1	0	2	44
	0.00	13.64	**65.91**	13.64	2.27	0.00	4.55	100.00
	0.00	4.58	**63.04**	24.00	6.67	0.00	15.38	13.92
	0.00	1.90	**9.18**	1.90	0.32	0.00	0.63	13.92
4	0	0	9	**11**	6	1	2	29
	0.00	0.00	31.03	**37.93**	20.69	3.45	6.90	100.00
	0.00	0.00	19.57	**44.00**	40.00	9.09	15.38	9.18
	0.00	0.00	2.85	**3.48**	1.90	0.32	0.63	9.18
5	1	0	2	6	**4**	3	1	17
	5.88	0.00	11.76	35.29	**23.53**	17.65	5.88	100.00
	1.33	0.00	4.35	24.00	**26.67**	27.27	7.69	5.38
	0.32	0.00	0.63	1.90	**1.27**	0.95	0.32	5.38
6	1	1	0	0	3	**3**	3	11
	9.09	9.09	0.00	0.00	27.27	**27.27**	27.27	100.00
	1.33	0.76	0.00	0.00	20.00	**27.27**	23.08	3.48
	0.32	0.32	0.00	0.00	0.95	**0.95**	0.95	3.48
7	2	0	0	0	0	3	**4**	9
	22.22	0.00	0.00	0.00	0.00	33.33	**44.44**	100.00
	2.67	0.00	0.00	0.00	0.00	27.27	**30.77**	2.85
	0.63	0.00	0.00	0.00	0.00	0.95	**1.27**	2.85
Total	75	131	46	25	15	11	13	316
	23.73	41.46	14.56	7.91	4.75	3.48	4.11	100.00
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
	23.73	41.46	14.56	7.91	4.75	3.48	4.11	100.00

Example: Looking at the first cell, 67 subjects reported a standard IOS score of 1 and a Step-Choice IOS score of 1. They represent 87.01% of the 77 subjects who reported a standard IOS score of 1 and 89.33% of the 75 subjects who reported a Step-Choice IOS score of 1. They also represent 21.20% of the 316 overall subjects

Bold indicates the diagonal where standard and Step-Choice IOS scores are equal one to another

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Data availability Our pre-registration is available at https://doi.org/10.17605/OSF.IO/Z6Y7D. Data and code to reproduce our results are available at https://doi.org/10.5281/zenodo.11913643. Our oTree code is available at https://doi.org/10.5281/zenodo.11913676.

Declarations

Conflict of interest We have no conflicts of interest to disclose.

Ethical approval The Connecticut College Institutional Review Board has approved the experiment reported in this paper.

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