**Human vs. Machine: The psychological and behavioral consequences of being compared
to an outperforming artificial agent**

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Abstract

While artificial agents (AA) such as Artificial Intelligence are being extensively developed, a popular belief that AA will someday surpass human intelligence is growing. The present research examined whether this common belief translates into negative psychological and behavioral consequences when individuals assess that an AA performs better than them on cognitive and intellectual tasks. In two studies, participants were led to believe that an AA performed better or less well than them on a cognitive inhibition task (Study 1) and on an intelligence task (Study 2). Results indicated that being outperformed by an AA increased subsequent participants' performance as long as they did not experienced psychological discomfort towards the AA and self-threat. Psychological implications in terms of motivation and potential threat as well as the prerequisite for the future interactions of humans with AAs are further discussed.

Keywords: Human-Machine interaction; Social comparison; Logical reasoning; Cognitive control

The future of humanity in regard to the evolution of Artificial Agents, such as Robots, Avatars or Artificial Intelligence, is a major topic in both sciences and public area. Here we define Artificial Agents as non-natural agents that act to achieve a goal upon an environment (e.g., an abstract functional system). While renowned scientists argue for a positive future with Artificial Agents (AA), others appeal for caution polarizing the public debate (Brewka, 1996; Lawless, Mittu, Russell, & Sofge, 2017; Perri, 2001). As the use of AA is being promoted in many areas of humans life (e.g., in computer, cellphones, cars, as medical diagnostic tool, to research case law, etc.) (Anderson, 2005; Brewka, 1996), the popular fear that AA could one day surpass human intelligence and control our world is also growing. One major concern in the field of AA is therefore the acceptance of such a powerful tool that will deeply transform the society we live in. In the next few years, humans will have to work hand-in-hand with AAs but the conditions under which such co-working situations can be effective remain largely unknown. In fact, researchers in psychology are neither able to predict how the interaction and coaction of humans and AA will unfold nor the psychological and cognitive impact it may have on individuals. Given the common belief that AA could eventually surpass human intelligence (Rigas, Booth, Briggs, Murata, & Stone, 1985), one may expect individuals to feel threatened in their self-worth when being outperformed by an artificial agent. If so, and based on findings from psychological research, threat to self-worth would be detrimental not only to individuals' self-esteem but also to their intellectual performance (Blascovich, Mendes, Hunter, & Salomon, 1999). The aim of the present article is therefore to investigate the psychological and behavioral impact of being favorably or unfavorably compared to a coacting AA.

Individuals cannot help but comparing themselves to others. Psychological research has intensively investigated the motivational factors of comparing oneself to others as well as the consequences on both psychological (e.g., self-esteem) and behavioral (e.g., performance outcomes) levels (for a meta-analysis, see Gerber, Wheeler & Suls, 2018). Individuals engage themselves in social comparison in order to assess their self-worth on many dimensions such as personality, physical appearance, ability, etc. If they have the opportunity, people seek comparisons with inferior targets (i.e., downward social comparisons; DSC) to gain self-confidence (Rubio & Deng, 2007) or with superior targets (i.e., upward social comparisons; USC) to get inspired (Wood, 1989). Nevertheless social comparisons are sometimes imposed to the individual and being compared to superior others is not always inspiring but threatening (Suls, Martin, & Wheeler, 2002). When exposed to a better-off peer, one may feel discouraged if reaching a higher standard seems impossible and self-esteem suffers from such threatening

USC (Lockwood & Kunda, 1997). On the behavioral level, performance outcomes of both USC and DSC depend on the cognitive processes engaged in the task and in the activity of social comparison itself. Indeed, comparing oneself to another person doing the same task involves paying attention to the other person (What he/she is doing?, How he/she is doing it?) and self-worries ('Am I good enough?'), which then consumes cognitive resources. In other words, social comparison activity distracts the individuals' attention away from the task at hand (Sanders, Baron, & Moore, 1978). Social comparison therefore triggers an attention conflict between considerations about one's ongoing level of performance and the task at hand. Such an attention conflict threatens the cognitive system with overload, which in turn may result in attention focusing on a smaller amount of information (Baron, 1986; Muller & Butera, 2007). When task demands exceed the individuals' resource leftovers (i.e., a complex task), performance would suffer leading to what has been referred to as 'social inhibition'. However greater focusing can be beneficial to performance and leads to 'social facilitation' when the task requires dealing little relevant information while ignoring other irrelevant information (i.e., an "easy" task). Whether threatening social comparison with another human being results in social facilitation or inhibition effects therefore depends on task difficulty. Using the Stroop task, Huguet, Galvaing, Monteil, and Dumas (1999) found support for the attention focusing effect of social comparison. The Stroop task requires individuals to identify the color in which a word is printed, ignoring the word itself. According to the distraction-conflict theory (Baron, 1986), the Stroop task is an "easy" task in the sense that it requires to focus on one type of information (the color in which a word is printed) while ignoring another piece of information (the meaning of the word itself; e.g., the word "BLUE" in green ink). Traditionally though, focusing only on the ink color can be experienced as difficult since reading the word is automatic and interferes with the correct answer (the Stroop interference). In accordance with the attention focusing hypothesis, Huguet and colleagues (1999) found that participants in presence of a coactor showed a reduced Stroop interference (i.e., a social facilitation effect), revealing a better ability to focus only on the ink color. The Stroop interference was even more reduced – and therefore attention even more focused – when the present coactor was outperforming the participants (i.e., USC). Recent research extended these findings by showing that attention focusing especially occurred when individuals compared themselves to an outperforming peer on an intelligence-related task (Normand & Croizet, 2013).

In sum, being compared to a better-off peer modulates cognitive processes by triggering attention focusing, especially when such comparison represents a threat to self-worth (e.g., is

related to general ability). One may question the possibility that being compared to better-off non-human agent such as an AA would produce the same social facilitation/inhibition effects. Indeed, comparing one's ability to an AA may just seem irrelevant and people may not even engage themselves in such comparison. But Spatola et al. (2018, 2019) provided a first glimpse on this matter. Using the same Stroop task, they found that the mere presence of a social robot doing the same task affected positively individuals' performance. The presence of artificial entities like social robots during task completion is therefore not neutral and, at least in some cases, seems to equate the presence of humans (Riether, Hegel, Wrede, & Horstmann, 2012; Spatola et al., 2019, 2018). Nevertheless, whether humans could consider AAs as valid targets of comparison remains unexplored. This postulate is even more critical considering that AAs are seen as potentially better than humans in specific tasks like logical reasoning, data analysis or strategy planning. Thereby, they could be seen as a valid USC targets to evaluate one's personal efficiency and thus, become a potential threat to humans' self-worth. This paper aims to provide a first answer to this question.

Study 1

Study 1 aims to investigate whether being compared with a superior or inferior AA can modulate participants' cognitive processes on a well-known cognitive performance measurement task: the Stroop task. The Stroop task requires individuals to identify the color in which a word is printed, ignoring the word itself. Because of the automaticity of word reading (Augustinova & Ferrand, 2014; Serrano-Cinca, Fuertes-Callén, & Mar-Molinero, 2005), identification times are consistently longer for color-incongruent words (the word "BLUE" in green ink) than for color-neutral items ("DESK" in green ink), a phenomenon typically referred to as "standard Stroop interference". This interference indicates how difficult the control of attention can be when faced with conflicting automatic activations. In line with previous research on the presence of both other human being (Muller & Butera, 2007) or social robot (Riether et al., 2012; Spatola et al., 2019, 2018), we hypothesized that being compared to an outperforming AA (i.e., USC) leads to a more focused attention than when being compared to an underperforming AA (i.e., DSC). For instance, Spatola et al. (2018) showed that the simple presence of a threatening robot resulted in a greater attention focusing in a Stroop task (i.e., a social facilitation effect) while the presence of a nice robot as well as no robot did not modulate individuals' performance outcomes. Since greater attention focusing has been found beneficial to performance on a Stroop task (Huguet et al., 1999), we further predicted that participants in the USC condition would show a smaller Stroop interference effect than participants in the DSC

condition. Moreover, given that the attention focusing hypothesis posits that it occurs specifically when the social comparison is self-threatening (Muller & Butera, 2007; Normand & Croizet, 2013), we also expected that participants in the USC condition would report a lower self-esteem than participants in the DSC and control conditions. Finally, because being compared to an AA represents a quite unusual situation, we included a measure of the perception of the AA: the Robotic Social Attributes Scale (Carpinella, Wyman, Perez, & Stroessner, 2017). In line with previous results from the literature, we expected that the more participants attribute discomfort and threatening traits to the robot the greater the performance modulation (Spatola et al., 2018), especially in the USC as compared to the DSC condition.

Method

Participants and design.

The sample size was determined on the basis of the desired power (.80), alpha level (.05), number of groups (three in the main analysis), number of measurement (two within Stroop sessions) and an anticipated effect size of $\eta^2_p = .08$. Indeed, previous research on human presence effects (Huguet et al., 1999) or on social comparison effects (Normand & Croizet, 2013) on Stroop interference and other attentional tasks revealed a small-to-medium size effect ranging from $\eta^2_p = .08$ to .10. Using G*Power 3.1 (Faul, Erdfelder, Lang, & Buchner, 2007), the minimum required sample size was 60. To be sure to reach this number of participants, we opened 90 slots for participants sign-ups and ran all participants that showed up. Eighty-one students (71 women, 10 men) from the Université Clermont Auvergne, France ($M_{age}=19.3$ years) took part in the study in exchange for course-credit. Upon arrival, they were individually informed that the study involved an AA in test and they were randomly assigned to one of the three in-between participants' conditions: USC, DSC and no social comparison.

Material.

Stroop task. The version of the task used consisted in two 96-trials sessions each composed of 48 standard color-incongruent words (e.g., BLUE in green) and 48 color-neutral words (e.g., DOG in green). The stimuli were matched for length and word frequency. The participants were instructed to indicate as quickly and as accurately as possible the color of the words presented by using a keyboard. The keys were labeled with colored stickers, with key "1" representing red, key "2" representing green, key "3" representing "blue" and key "4" representing "yellow".

Artificial Agent design. The AA was designed with a non-anthropomorphic look in order to make it clearly non-human. However, the visualization of the AA was dynamic and its

movements were congruent with its speech. To do so, we used the experimental website <https://www.yuichiroharai.com/experiments/fluid/> (cf. Figure 1). All the AA interaction were recorded on different video and integrated in the E-prime program to appear in the upper right corner of the screen in a 5x5 cm format. The center was positioned at 85% on the x axis and 15% on the y axis of the screen. The AA was not displayed during the task.

Fig 1. Avatar of the Artificial Agent

Attribution of social characteristics to the AA. At the end of the experiment, participants in the two social comparison (USC and DSC) conditions completed the Robotic Social Attributes Scale (RoSAS) (Carpinella et al., 2017). The RoSAS allows assessing the extent to which participants attribute social characteristics to robots along three dimensions: perceived warmth (e.g., “happy”) ($\alpha = .82$); perceived competence (e.g., “capable”) ($\alpha = .81$); and perceived discomfort (e.g., “dangerous”) ($\alpha = .79$). For each dimension, participants expressed their level of agreement as to whether each attribute defined the AA.

Self-Esteem. Participants filled out the Rosenberg self-esteem scale (Dalrymple & Herbert, 2007; Serrano-Cinca et al., 2005) as an indicator of their current level of self-esteem. For each proposition they had to rate to what extent the affirmations matched their own feeling (e.g., “On the whole, I am satisfied with myself” from 1 to 4) ($\alpha = .51$)¹.

Knowledge about robot. Participants in comparison conditions finally had to answer one question about their level of knowledge about artificial intelligence and robots on a scale going from 1 “no knowledge” to 7 “professional knowledge”. The overall mean of participants was 1.9 ($SD = 0.4$), indicating a low level of familiarity with AA.

Procedure. Upon arrival, participants were introduced with the experimental setting and told that they will perform one cognitive task with an AA performing the same task simultaneously. The AA was actually bogus and was incarnated by a preregistered video presented in the upright corner of the participants’ screen. In both social comparison conditions, the AA played the role of the experimenter and asked participants to perform a Stroop task. All

¹ Alphas less than 0.7 are considered as non-reliable (Cronbach, 1951; James Dean Brown, 2002).

the subsequent instructions given by the AA and interactions with the participants followed a pre-established script. Participants were instructed to identify the color of the letter-strings presented on the screen as quickly and accurately as possible while ignoring their meanings either for incongruent color words (i.e., BLUE in green) or neutral words (i.e., DOG in green). The difference between trials conditions (i.e., incongruent color words minus neutral words) is labeled Stroop interference (for more details see Supplementary Materials). After the first session, participants received a bogus (pre-established) performance score and could see the AA's performance score allowing for the social comparison manipulation. The AA performance was set to be either superior (i.e., USC condition) or inferior (i.e., DSC condition) to the participants' bogus score. The score of the participant was fixed at 116.3. In the downward comparison condition, the score of the AA was 102.6 while in the upward comparison condition the score of the AA was 132.6. To ensure that they read the scores, the AA asked participants to remember these scores until the end of the experiment. The AA then invited participants to perform a second session of the Stroop task (allowing the performance measure). Participants in the control condition only received the individual bogus score before moving to the second session of the Stroop task. At the end of the second session, participants filled out the self-esteem evaluation scale and the RoSAS. They were finally probed for suspicion, debriefed and thanked.

Results²

Two participants were suspicious about the AA bogus apparatus and were therefore excluded from analyses. Correct trials with a response time (RT) lower or higher than 3 standard deviations per condition for each participant were considered outliers and were then removed from RT analyses (1.26% of the trials). Such trimming procedure has the advantage of taking out extreme values without affecting the data of one condition or of one participant in particular (Lachaud & Renaud, 2011). The standard Stroop interference was computed as follows: RTs for standard color-incongruent words minus RTs for color-neutral words.

Participants' RTs on the Stroop task were submitted to a 2 (Session: Session 1, Session 2) x 2 (Trials congruency: color-incongruent vs. color-neutral words) x 3 (Social comparison:

² Data are available at <https://osf.io/t9z6r/>

Control, DSC, USC) mixed-ANOVA with the two first factors manipulated within and the last one in-between participants. For similar analyses, see Spatola et al. (2018, 2019)³.

Table 1. Mean correct response times (in milliseconds), standard error (in parentheses) and accuracy rates (in italic) as a function of trials congruency and social comparison conditions.

		Social comparison conditions					
		Control		Downward comparison		Upward comparison	
		Session 1	Session 2	Session 1	Session 2	Session 1	Session 2
Standard color-incongruent		751	742	746	744	796	733
		(22.37)	(18.09)	(22.37)	(17.92)	(22.81)	(19.41)
		.98	.9	.98	.98	.97	.99
Color-neutral words		696	710	703	722	736	724
		(19.03)	(17.91)	(18.09)	(17.92)	(18.45)	(18.27)
		.97	.98	.99	.98	.98	.98
Stroop Interference		55	32	43	22	60	9
Standard Stroop interference	F statistic	$F(1, 74)=31.45$	$F(1, 74)=17.29$	$F(1, 74)=19.15$	$F(1, 74)=7.66$	$F(1, 74)=36.18$	$F(1, 74)=13.66$
	P value	$p<.001$	$p<.001$	$p<.001$	$P=.007$	$p<.001$	$p=.264$
	Effect size	$\eta_p^2=.30$	$\eta_p^2=.19$	$\eta_p^2=.2$	$\eta_p^2=.09$	$\eta_p^2=.33$	$\eta_p^2=.02$

In conformity with our prediction, the interaction of Session, Trials congruency and Social comparison was significant, $F(2, 74) = 4.52$, $p = .014$, $\eta_p^2 = .11$ (cf. Figure 2). Participants' Stroop interference score (mean $RT_{\text{color-neutral}} - \text{mean } RT_{\text{color-incongruent}}$) was significant in the control, DSC and USC conditions in both sessions except the second session in USC condition (cf. Table 1). To provide a direct test of our hypothesis, contrast analyses were conducted to verify that Stroop performance improvement from S1 to S2 was indeed superior in the USC condition as compared to the other social comparison conditions (control and DSC). As predicted, results showed that participants' Stroop performance improvement was significantly higher in the USC condition (coded 1) than in the control (coded -0.5) and DSC (coded -0.5) conditions, $t(74) = 3.01$, $p = .004$, $\eta_p^2 = .10$. Stroop interference scores in Control and DSC conditions did not differ from each other [$t(74) = -.10$, $p = .918$, $\eta_p^2 < .01$]. We also controlled that they were no Stroop interference differences in Session 1 (all $p_s > .20$). Of lesser interest, we also found a main effect of the Trials congruency [$F(1, 74) = 63.60$, $p <$

³ For second session analyses similar to Normand & Croizet (2013), see Supplementary Material

.001, $\eta_p^2 = .46$], participants were faster on color-neutral than color-incongruent trials. The main effect of the experimental group was non-significant, $F(2, 74) = .428, p = .654, \eta_p^2 = .01$.

Fig 2. Stroop performance improvement between sessions (in ms) in function of the condition (control, downward comparison, upward comparison). The higher positive value, the higher the Stroop Interference reduction. Error bars represent 1 standard error.

Moreover, given that the attention focusing hypothesis posits that it occurs specifically when the social comparison is self-threatening (Muller & Butera, 2007; Normand & Croizet, 2013), we also expected that participants in the USC condition would report a lower self-esteem than participants in the two others conditions. A regression analysis was conducted on self-esteem reports with Social comparison as an independent variable (Control = coded -0.5 ; DSC = coded -0.5; USC = coded 1). The result was non-significant, $b = -1.15, t(76) = -.87, p = .388, \eta_p^2 = .01$. In line with previous results from the literature, we expected that the more participants attribute discomfort and threatening traits to the AA the greater the performance modulation (Spatola et al., 2018), especially in the USC as compared to the DSC condition. Separate regression analyses were conducted to analyze the potential role of warmth, competence and discomfort perceptions of the AA in the Stroop interference modulation across session and as a function of social comparison conditions (USC vs. DSC). The interaction of social comparison and discomfort was significant, $b = -.48, t(53) = -3.49, p = .001, \eta_p^2 = .20$. Participants in USC condition attributed more discomfort to the AA than participants in DSC condition [$F(1, 53) = 7.10, p = .002, \eta_p^2 = .22$] and the higher participants attributed discomfort traits to the AA the lower their Stroop interference, $b = -.31, t(53) = -2.29, p = .027, \eta_p^2 = .10$. No other effect reached significance (all $ps > .10$).

Discussion

Results from Study 1 provided first evidence that being compared to an AA is not psychologically neutral and somehow impacts individuals' performance outcomes as previously observed in human-human social comparison settings. Participants placed in a condition where their performance was lower than the AA's performance (i.e., USC condition) showed a reduced Stroop interference (i.e., a performance improvement). This finding is compatible with the attention focusing account deriving from the distraction-conflict theory (Baron, 1986). This account suggests that USC leads to higher attention focusing on relevant information (here, the color of the words) at the expense of competing cues (the meaning of the words) thereby resulting in a reduced Stroop interference (Huguet et al., 1999; Muller, Atzeni, & Butera, 2004).. According to the distraction-conflict theory (Baron, 1986), USC has indeed the potential for distracting individuals from the ongoing task and consequently triggering attention conflict. Such conflict would threaten the organism with cognitive overload and, ultimately, cause a restriction in attention focus. A restricted attention focus is thought to be detrimental to complex tasks in which much information is involved and better processed with a broad attention focus. Conversely, a restricted attention focus is supposed to be beneficial to easy tasks in which only one type of information must be processed while other information must be neglected. According this definition of easy vs. difficult tasks, the Stroop task is an easy one and so the attention focusing should result in higher performance (i.e. a better ability to deal with the Stroop interference). However a mere motivational account could also explain the present findings. One may argue that in the USC condition, participants simply put more effort in the task to match the standard fixed by the outperforming AA (see Muller & Butera, 2007 for a similar contention). In addition, the recent version of the attention focusing hypothesis posits that USC would trigger a distraction-conflict especially when the comparison with others is self-threatening (Muller & Butera, 2007; Normand & Croizet, 2013). Here we found no sign of such self-threat since participants' in the USC condition did not report experiencing a lower self-esteem than participants in the two other conditions. The absence of effect on self-esteem could nevertheless be attributed to the scale used whose reliability turned out low ($\alpha = .51$). Moreover, it is worth noting that the framing of task (i.e., merely introduced as a 'cognitive task') may not have triggered a threat to self-worth as intelligence tests do (Normand, Bouquet, & Croizet, 2014; Normand & Croizet, 2013; Tesser, 1988). Finally, we found that perception of discomfort towards the AA was positively linked to better Stroop

performance across social comparison conditions. At this point, it therefore seems premature to simply conclude that being compared to a superior AA is merely a source of positive motivation since feelings of discomfort seem to be involved in the situation. Study 2 was designed to further test the psychological impact of being compared to an outperforming AA on cognitive performance by using the Raven's Progressive Matrices. This task allows a stronger test of our hypothesis because 1) it is more complex than a Stroop task (Study 1) and high attention focusing should then be detrimental to performance outcomes, and 2) it is an intelligence task described as such to participants and is therefore likely to represent a threat to self (i.e., a fear to be or to look unintelligent).

Study 2

Study 2 aims to test whether being compared to an AA on an intelligence test (e.g., the Raven's Progressive matrices, RPM (Raven, 2000; Raven, 1941)) – rather than a Stroop task – represents a potential threat to participants' self-image. The RPM are commonly used in education or military to assess for Intelligence Quotient (IQ); two places where AAs will actually be implemented (Ayoub & Payne, 2016; McArthur, Lewis, & Bishary, 2005). They are traditionally considered as a standard measure (Fumi & Parr, 1953) of abstract reasoning and fluid intelligence (Harrison, Shipstead, & Engle, 2015). Achieving the RPM requires to deduce abstract relations and to dynamically manage a large set of problem-solving goals in working memory (Carpenter, Just, & Shell, 1990). Our reasoning was that when the task is supposed to reveal one's level of intellectual ability, being outperformed by an AA (i.e., USC) would trigger self-worries and ruminate thoughts (e.g., "I'm less intelligent than an artificial intelligence"). Such interfering thoughts would consume cognitive resource and constrain the system to focus resource leftovers on a smaller amount of information. Contrary to the Stroop task, intelligence tasks such as the RPM are more complex and require processing and manipulating much more information. In line with previous research on self-evaluative threat and according to the attention focusing account (Muller & Butera, 2007; Normand & Croizet, 2013), we therefore hypothesized that participants in the USC condition would experience a self-threat that consumes cognitive resource and subsequently restricts the attention focus. Given the complexity of the task, we hypothesized that a restricted attention focus would not match task demands and that performance would consequently decrease. An alternative motivational account would lead to the opposite prediction that being compared to an outperforming AA encourages individuals to put more effort in the task at hand, which would result in – not a decrease – but an increase of performance. As in Study 1, participants' self-esteem was also assessed as well as their tendency to attribute social characteristics to the AA

(warmth, competence and discomfort). Here again, we predicted that participants in the USC condition experience self-threat and thus report lower levels of self-esteem and higher levels of psychological discomfort towards the AA. Finally and for exploratory purpose, we hypothesized that the more participants in USC condition report psychological discomfort towards the AA, the lower their performance on the intelligence test.

Method

Participants and design.

The target sample size was the same as Study 1 and we again opened 90 slots for participants sign-ups. As a result, seventy-five students (68 women, 7 men) from the Université Clermont Auvergne, France ($M_{age}=19.6$) took part in the study in exchange for course-credit. Upon arrival, they were individually informed that the study involved an AA in test and they were randomly assigned to one of the three in-between participants' conditions: USC, DSC and no social comparison. One participant was finally excluded from the analysis in reason of suspicion regarding the AA deception.

Material

Raven's Matrices. Twenty-four Raven's Matrices were borrowed from the Standard D and E sets. Each matrix represents a 3 X 3 pattern of symbols with the last one missing. Participants are presented with 8 choices to pick from and fill the missing space in the matrix. We used E-Prime 2.1 for stimulus presentation and data collection. The participants were seated approximately 50 cm from a 17-inch Dell color monitor.

Attribution of social characteristics to the AA. The same as Study 1's Robotic Social Attributes Scale (RoSAS) was used (Carpinella et al., 2017). Cronbach's alphas were reliable for Discomfort ($\alpha = .71$) and Warmth ($\alpha = .79$), but not for Competence ($\alpha = .59$).

Self-Esteem. The same scale as in Study 1 was used ($\alpha = .61$).

Knowledge about robot. Again we controlled for the level of knowledge of participants about robots and AA. The overall mean of participants was 2.3 ($SD = 0.5$) and once again indicated that participants were not familiar with AA.

Procedure. The procedure was the same as Study 1 except for the following. The two Stroop task sessions used in Study 1 were replaced by a two 12-Raven's Matrices sessions (Standard version, sets D & E). Participants were instructed to find the logical continuation of different matrices in 30s and to give their response on the keyboard. The twelve matrices were presented in the same order as planned by the Raven test (D1 to D12, average difficulty). In the

AA comparison conditions, a score-loading screen was presented after the first session. In order to make the task performance relevant to self-image, the AA informed the participants that the score was reflexive of their logical intelligence. The manipulation of social comparison was identical to Study 1 except that no score was presented in the control condition to avoid any self-evaluation opportunity. Participants then moved to the second session with 12 new matrices presented with the same previous parameters (E1 to E12, high difficulty). Response time and accuracy were recorded. At the end of the second session, participants filled out the self-esteem evaluation scale and the RoSAS. They were finally probed for suspicion, debriefed and thanked.

Results

Analyses were conducted on the composite linear integrated speed-accuracy score (LISAS) (Vandierendonck, 2017, 2018). The LISAS score represents response times weighted by the amount of incorrect responses. The higher the LISAS, the less performing were participants. LISAS is defined as: $LISAS = RT_j + S_{RT} S_{PE} \times PE_j$ with RT_j as the participant's mean RT in condition j , PE_j as the participant's proportion of errors in condition j , S_{RT} as the participant's overall RT standard deviation, and S_{PE} as the participant's overall PE standard deviation. According to Vandierendonck (2018), such a composite score “yields an estimate of RT corrected for the number of errors.” (see Table 2), which seems relevant to Raven's matrices performance assessment since both accuracy and response time matter (Stankov & Schweizer, 2007).

Table 2. LISAS score (in milliseconds) and standard error (in parentheses) as a function of the social comparison condition.

	Control	Downward comparison	Upward comparison
Raven's Matrices scores	37251 (2586)	36691 (1063)	29327 (2482)

Unlike Study 1, analyses were only conducted on the Session 2. Given the difference in difficulty levels, performance in Session 1 is indeed not comparable to performance in Session 2. Here, Session 1 only served as a pretext for introducing a performance score comparison between the participants and the AA⁴. We conducted a ANOVA with the LISAS score in

⁴ However we controlled that participants' performance on the Raven matrices did not differ in Session 1, $F(2, 73) = 429$, $p = .653$, $\eta_p^2 = .012$.

Session 2 as a dependent variable and the social comparison condition as an independent variable (see Gerber et al., 2018). Results showed a main effect of social comparison, $F(2, 73) = 3.52, p = .035, \eta_p^2 = .09$, (cf. Figure 3). Contrasts showed that in Session 2, participants in USC condition performed better than participants in the two other conditions, $F(1, 73) = 5.86, p = .018, \eta_p^2 = .08$. Participants' performance in control and DSC conditions did not significantly differ, $t(71) = -.18, p = .868, \eta_p^2 < .01$.

The same ANOVA but with self-esteem reports as a dependent variable was also conducted. The analysis showed a main effect of social comparison condition on self-esteem, $F(2, 73) = 5.96, p = .004, \eta_p^2 = .144$. Participants in the USC condition expressed a lower self-esteem than participants in the two other conditions [$t(71) = -3.41, p = .001, \eta_p^2 = .19$; with the control and the DSC conditions not differing from each other, $t(71) = .53, p = .596, \eta_p^2 = .01$].

Fig 3. LISAS score (time to produce a correct response) in Session 2 as a function of social comparison condition (Control, downward comparison, upward comparison). The higher the score, the lower the performance is. Error bars represent 1 standard error.

A separate regression analysis was conducted on Raven Matrices performance in session 2 with self-esteem reports, social comparison (USC vs. DSC) and the interaction term as predictors. In addition to the main effect of social comparison that was still significantly related to performance outcomes, $b = -.48, t(49) = -3.25, p = .002, \eta_p^2 = .19$, we found a main effect of self-esteem, $b = -.32, t(49) = -2.15, p = .037, \eta_p^2 = .09$. The lower participants' reported self-esteem and longer they needed to produce a correct answer (i.e., the lower their performance).

Three additional regression analyses were conducted on Raven Matrices performance in session 2, each including one of the three dimensions from the RoSAS (Discomfort, Warmth, and Competence), social comparison (USC vs. DSC) and the interaction term as predictors. For exploratory purpose, we hypothesized that the more participants in USC condition report psychological discomfort towards the AA, the lower their performance on the intelligence test. Confirming this hypothesis the interaction between social comparison and discomfort was also significant, $b = .38$, $t(49) = 2.96$, $p = .005$, $\eta^2_p = .16$. In USC the more participants attributed discomfort traits to the AA, the slower they were to produce a correct answer, $b = .55$, $t(24) = 3.19$, $p = .004$, $\eta^2_p = .31$. This effect was not significant in DSC comparison, $b = -.35$, $t(24) = -1.78$, $p = .087$, $\eta^2_p = .12$. The main effect of comparison was also significant, $b = -.35$, $t(49) = -2.43$, $p = .019$, $\eta^2_p = .02$. There was no main effect of discomfort attribution on performances, $b = -.01$, $t(49) = -.04$, $p = .973$, $\eta^2_p < .01$. Regarding warmth attribution, the social comparison main effect was significant and in the same direction as above, $b = -.39$, $t(49) = -2.71$, $p = .009$, $\eta^2_p = .14$. The main effect of warmth and the interaction term were not significant ($p_s > .30$). Finally, in competence attribution model, only the social comparison main effect was significant $b = .34$, $t(49) = -2.49$, $p = .017$, $\eta^2_p = .12$. No other effects reached significance ($p_s > .25$).

Discussion

The two experimental studies reported in the present paper aimed at investigating the psychological and behavioral impact of being favorably (DSC) or unfavorably (USC) compared to a coacting AA. We postulated that AA could be seen as valid targets of comparison and thus trigger a threat to the self (i.e., a fear of intellectual inferiority) when humans are being unfavorably compared to them. Based on previous research in psychology, we hypothesized that self-threat modulates cognitive functioning and induces greater attention focusing. Such attention focusing is known for being beneficial to performance outcomes on easy tasks but detrimental on more complex tasks on which focusing attention may lead to information neglect (Baron, 1986). Results from Study 1 were compatible with the attention focusing account by showing that the interference in a Stroop task was smaller when participants were placed in a condition where they could compare themselves to a better-off AA. The Stroop task can indeed be considered as an “easy” task since achieving it consists in dealing with incongruent information, which requires focusing on only one type of information (i.e., the ink color) while neglecting other information (i.e., the meaning of the word). However, results from Study 1 left

open an alternative explanation in terms of greater effort put in the task, resulting in higher performance. The possibility of an increase of motivation rather than attention focusing is all the more likely that participants from Study 1 may not have experienced self-threat, which has been found to be a prerequisite of the attention focusing effect (Normand & Croizet, 2013). Study 2 was therefore designed to disentangle a motivational from an attention focusing account by using a performance task labeled as an “intelligence task” and of higher complexity. Both the nature (i.e., an abstract reasoning task on which no information must be neglected) and the framing of the task (i.e., reflecting intellectual ability) were supposed to create the conditions for attention focusing to disturb performance and for self-threat to arise (Muller & Butera, 2007; Normand & Croizet, 2013). Results from Study 2 nevertheless demonstrated that participants who were led to compare themselves with a better-off AA (USC) were not less but more efficient on the intelligence task (i.e., shorter time to produce a correct response). At first sight, this finding is not in accordance with the literature on human-human social comparison suggesting that upward social comparison is often associated with self-threat and performance decrements (Testa & Major, 1990). It is neither compatible with a solely attention-focusing account that predicts performance improvement on easy tasks (Study 1) and decrements on complex tasks (Study 2) that require a large breadth of attention to consider all relevant information. In Study 2, rather than experiencing a disruptive attention focusing, participants in this condition seemed, on the contrary, to have been able to put more effort in the task and be more efficient to solve analytical problems.

On the one hand, comparing individuals to AA does seem incidental to human performance but on the other hand, such comparison does not reproduce the psychological impact of human-human social comparisons. One reason why this nature of comparison may lead to different outcomes could be that the level of performance of an AA is not relevant to humans’ self-image as human-human social comparisons are. The comparison to an AA would then be less “social” in nature than expected and may instead be similar to the experience of video game players who loses against the computer: rather than feeling truly “self-threatened” by the computer, it sets a challenging standard to beat and motivates the players (Przybylski, Rigby, & Ryan, 2010).

Nevertheless, the video-game metaphor does not fully account for the present findings. Analyses indeed indicated that the performance boost in USC conditions was partially driven by higher feelings of discomfort (i.e., perception of danger) towards the AA. Such findings suggest that being compared to an outperforming AA may not only be a source of positive

motivation and challenge (as playing against the computer in video games can be), but may also involve more negative feelings such as psychological discomfort. Accordingly, we also found that participants in Study 2 (involving the completion of an intelligence test) reported a lower level of self-esteem, which was negatively linked to the time needed to produce a correct answer. This last result is also in line with the idea that being compared to a superior AA is somewhat psychology uncomfortable. However, the self-esteem measure used in the present research revealed to be quite unreliable and replications with other self-esteem measures is necessary for clarifying this matter. Taken together, the present findings nevertheless suggest that competing against an AA may represent an encounter of the third kind, falling somewhere in-between competing against another human and competing against the computer, and involving mixed feelings of motivational challenge and psychological discomfort.

The present research has several limits. First, a majority of the participants were women. Studies have already demonstrated that men and women react differently in front of artificial agents (Nomura, 2017). For instance, men tend to attribute more anthropomorphic characteristics to robots than women, and are more “socio-cognitively” responsive (Schermerhorn, Scheutz, & Crowell, 2008). A gender difference also appears on attitudes toward AA, with more positive attitudes hold by men (Heerink, 2011; Kuo et al., 2009). There is therefore a possibility that gender interacts with the present findings. On the one hand, being compared to a superior AA might result in increased socio-cognitive effects among men due to their greater tendency for robots’ anthropomorphization, which appears to be an important mechanism in human-AA interaction (Spatola et al., 2019). On the other hand, the more negative attitudes hold by women could catalyze higher feelings of threat (Blascovich et al., 1999) and thus also result in increased socio-cognitive effects when confronted to a superior AA. Anyhow, whether gender plays an important role in the cognitive and psychological effects of human-to-AA comparison settings remains an open question. Second, and as mentioned earlier, the self-esteem scale used in both studies showed a low reliability. Whether this validity issue arises from a mismatch between the specific nature of the experimental situation and the items from the scale or social desirability that may have occur after participants’ received an evaluation of their performance (Paulhus, 2013) remains unclear. Third, participants in both studies reported having only little knowledge about AA. It is therefore possible that they held erroneous preconceptions about what an AA is and more generally, how does artificial intelligence work. For that matter, believing that the AA is capable of improvement (i.e., an incremental system) or not (i.e., a fix system) might be an important moderator of the present results. One may argue that the greater perceptions of discomfort (e.g., of danger) towards the

AA that participants in USC conditions reported are fueled by the belief that the AA was capable of improvement and could outperform them even more in the second round. Thinking that the AA can learn and may get even better in the future could have a strong influence on cognitive performance by rising levels of uncertainty and lack of control over outcomes (Mushtaq, Bland, & Schaefer, 2011). Future research is needed to address the issue of the psychological impact of individuals' belief regarding artificial agents and more specifically artificial intelligence as systems capable of learning and self-improvement.

Conclusion

The present research aimed to examine whether the common belief that AA may someday surpass human intelligence translates into negative psychological and behavioral consequences when individuals are exposed to an outperforming AA. The results from two studies indicated that the effects on individuals are mixed: Individuals' performance increases but at the cost of greater psychological discomfort. In sum, being outperformed by an artificial agent may represent – at least for now – a third type of social comparison whose psychological and behavioral outcomes fall somewhere in-between comparing oneself to another human being and competing against the computer. Overall, the present research highlights the fact that interacting with AA is far from being psychologically neutral and has the potential for greatly impacting humans' psychological life in the years to come.

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