"Fire! Do Not Fire!": A new paradigm testing how autonomous systems affect agency and moral decision-making

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1   **"Fire! Do Not Fire!": A new paradigm testing how autonomous systems affect agency and**

2   **moral decision-making**

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15 **Abstract**

16 Autonomous systems have pervaded many aspects of human activities. However, research suggest

17 that the interaction with those machines may influence human decision-making processes. These

18 effects raise ethical concerns in moral situations. We created an ad hoc setup to investigate the

19 effects of system autonomy on moral decision-making and human agency in a trolley-like

20 dilemma. In a battlefield simulation, participants had to decide whether to initiate an attack

21 depending on conflicting moral values. Our results suggest that our paradigm is suitable for future

22 research aimed at understanding the effects of system autonomy on moral decision-making and

23 human agency.

24

25 **Keywords:** Human-autonomous systems interaction; Human performance; Level of system

26 autonomy; Moral decision-making; Sense of agency

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28   **1. Introduction**

29   In the last decades, the use of autonomous systems has become increasingly widespread in

30   various fields of human activity. From driving (Ayoub et al., 2019; Chan, 2017) to aviation

31   (Anderson et al., 2018; Chialastri, 2012; Valdés et al., 2018), medicine (Kawamoto et al., 2005;

32   Sutton et al., 2020), and military defense and security (Mayer, 2015), there is almost no area where

33   these technologies are not massively deployed. As these technologies become more widespread,

34   the inevitable trend toward even more machine autonomy will lead to profound changes in the role

35   played by humans during the execution of tasks. From workers in industry, agriculture, and

36   transportation, to consumers in their daily lives, advances observed in technologies show that

37   humans are rapidly moving from the position of direct tasks executors (with the help of

38   mechanistic machines) to supervising tasks performed directly by intelligent machines with high

39   level of autonomy.

40   The main reason for the massive deployment of autonomous systems resides in the many

41   benefits these systems offer to users. Several laboratory experiments have shown that the

42   introduction of some level of autonomy in tasks can have substantial effects in terms of users'

43   decision-making and performance. For example, studies have shown that autonomous systems can

44   help people in detecting task-relevant cues and ignoring irrelevant cues in the environment

45   (Chavaillaz et al., 2018; Goh et al., 2005), improve the decisions made by human subjects in

46   complex situations and reduce the number of errors they make (MacMillan et al., 1997; Rovira et

47   al., 2007; Sarter & Schroeder, 2001), or even reduce the time to make correct decisions (Chavaillaz

48   et al., 2018). In addition, the introduction of autonomy has been shown to reduce users' mental

49   workload and thus increase their ability to monitor multiple tasks simultaneously (e.g., Chen &

50   Barnes, 2012; Wright et al., 2018). Laboratory experiments have also shown that the effects

51 produced by the interaction with autonomous systems on human decision-making and performance

52 depend on several factors (Parasuraman & Riley, 1997; Mosier & Manzey, 2019). In particular,

53 autonomous systems operating at the decision stage of a task or with a high level of autonomy are

54 generally associated with the largest benefits in terms of human performance (e.g., Endsley &

55 Kaber, 1999; Manzey et al., 2012; Rovira et al., 2007). Based on these results, one could easily

56 conclude that more autonomy is always better for the users, whether they are pilots flying on a

57 plane, physicians analyzing the test results from a patient, or military drone operators deployed in

58 a war zone.

59   However, the involvement of autonomous systems technologies into human activities has

60 not been systematically associated with positive effects. Several studies have shown that their use

61 can also have significant negative effects. Parasuraman et al. (1993) provided a classic

62 demonstration thereof. They reported low level of detection of automation failures with highly

63 reliable systems, an effect they called automation complacency (also named automation

64 overreliance). Other examples of negative effects are loss of situational awareness (Endsley, 2017),

65 skill decay (Haslbeck & Hoemann, 2016; Volz & Dorneich, 2020), performance decrement in

66 return-to-manual control (Endsley & Kiris, 1995), or increased workload with too many

67 autonomous systems to monitor (Wang et al., 2009). Interestingly, the detrimental effects caused

68 by the cooperation with autonomous systems seem to be directly related with the stage and level

69 of autonomy of those systems. For example, Rovira et al. (2007) reported lower rates of correct

70 decisions with highly reliable systems with high levels of autonomy (i.e., decision systems)

71 compared to systems with lower levels of autonomy (i.e., information systems). Thus, while more

72 autonomy seems to be clearly beneficial when the system's recommendations are correct, the

73   negative effects seem also to be more pronounced for higher levels of autonomy in machines that

74   are, most of the time, imperfect.

75   In this context, another important aspect of human-autonomous systems interaction that

76   has received increasing attention in recent years is the impact of autonomy on human agency

77   (Berberian, 2012, 2019, Coyle et al., 2012; Zanatto et al., 2021). The sense of agency (SoA),

78   defined as the *feeling of causing changes in the external world by controlling one's own voluntary*

79   *actions* (Jeannerod, 2003; Haggard, 2017; Burin et al., 2017; Pyasik, Salatino et al., 2019), is

80   recognized as an important aspect of human consciousness. Because SoA enables us to perceive

81   ourselves as causal agents, it is the basis for intentional behavior (Haggard & Tsakiris, 2009), and

82   is closely related to moral responsibility (Moretto et al., 2011; Caspar, Christensen, Cleeremans,

83   & Haggard, 2016).

84   The recent interest in this topic has been triggered by the possibility offered by the

85   "Intentional Binding" effect to implicitly measure the SoA. The Intentional Binding is a

86   phenomenon by which the perceived time between an action and its outcomes is modulated by the

87   intentionality of that action. Time appears compressed in situations where the person is active,

88   while time appears stretched in situations where the person is passive (Haggard et al., 2002).

89   Measuring the SoA by using this effect usually consists of asking subjects to estimate the time

90   interval between an action they perform and the consequences of that action. Numerous studies

91   have now shown that the time estimation between action and outcome is a valid implicit measure

92   of SoA (e.g., Christensen et al., 2019; Imaizumi & Tanno, 2019; Malik & Obhi, 2019; Haggard,

93   Clark, and Kalogeras, 2002; Moore and Obhi, 2012) and is preferable to a subjective measurement

94   of responsibility, which is usually obtained by a direct report of how people attribute the effects of

95   their own actions (Saito et al., 2015), which is subject to social desirability and other biases (e.g.,

96   Blackwood et al., 2003; Wegner & Withley, 1999).

97   In one of the first studies investigating the effects of autonomy on SoA by using the

98   Intentional Binding paradigm (Berberian et al., 2012), participants took part in a flight simulation

99   and were assisted in their task by different levels of automation. Berberian and colleagues' results

100 showed a decrease in SoA with increasing levels of automation, suggesting that agency decreases

101 with higher levels of automation. Further evidence using the same paradigm can be found in the

102 study by Coyle and coworkers (2012), who investigated how assistance, in a machine-assisted

103 point-and-click task, affects the user's SoA. Their results suggest that, up to a certain point, the

104 computer could assist users while also allowing them to maintain a sense of control over their

105 actions and outcomes, hence of their agency. More recently, Zanatto et al. (2021) showed a similar

106 negative impact of automation on SoA, and that the mental workload may also play a role in

107 reducing agency. Taken together, these studies suggest that automation technology may affect the

108 mechanism underlying human agency.

109   Hence, the evidence of negative effects on human decisions and performance, and the

110 evidence of a decrease in the implicit and explicit SoA (Berberian et al., 2012; Coyle et al., 2012;

111 Vantrepotte et al., 2022), that might result from the interaction with the autonomous systems, have

112 serious performance and safety implications. Engineers working on the development of new forms

113 of autonomous technologies should be aware of these effects and take them into account.

114 Furthermore, these results have important implications when those systems are used in sensitive

115 or moral domains such as in medicine or in the military, in which decisions of life and death have

116 to be made.

117   To date, however, very little is known about how the interaction with an autonomous

118   machine affects SoA and the decisions made by someone engaged in a moral scenario, and how

119   this is influenced by the level of autonomy of the system. Indeed, it is possible that interacting with

120   autonomous systems to make moral decisions negatively affects the moral and ethical decision-

121   making process and the resulting actions, particularly in tasks and domains of moral value such as

122   in the military context (Christensen et al., 2012; Cushman et al., 2013, 2017).

123   In recent years, research in the field of moral decision making and autonomy has focused

124   mainly on the rules and/or algorithms that can be assigned to an autonomous system to perform

125   ethical responses in moral situations (Arkin et al., 2011; Jiang et al., 2021). Surprisingly, until

126   recently, little attention has been paid to understanding how a human agent's ethical behavior in

127   moral decision-making situations can be influenced by its interaction with an autonomous system

128   (Köbis et al., 2021). The available data suggest a mixed picture of the effects of autonomous

129   systems in social and moral decision-making situations. Indeed, while some recent evidence

130   suggests that interaction with automation could lead to the promotion of prosocial behaviors (such

131   as fairness and cooperation, see, e.g., de Melo et al., 2018, 2019), other studies have shown that it

132   could also lead to unethical behaviors (Cohn et al., 2022; Leib et al., 2021). Concerning SoA, while

133   some studies report that a moral context increases it (e.g., Moretto et al., 2011) and that a higher

134   SoA is associated with higher prosocial decision-making (Caspar et al., 2022), it is not clear

135   whether this is still true when decisions are made in collaboration with an autonomous intelligent

136   machine.

137   Considering the lack of research on how autonomous systems impact the SoA and decision-

138   making in a moral context, and how this can be modulated by the level of autonomy of the system,

139   in the present study, we aimed to build an ad hoc setup to investigate how the level of system

140   autonomy affects SoA and the moral decision-making. To this end, we developed a task in which

141   participants (military cadets) played the role of drone operators on a simulated battlefield and had

142   to decide whether or not to initiate an attack, based on the presence of enemies and the risk that

143   allies might also be harmed. Participants were exposed to three types of trials representing three

144   types of uncertainty (*Moral Decision-Making* Trials, *No Risk* Trials, and *No Enemy* Trials) with

145   three different levels of system autonomy, including no system assistance, information assistance

146   (i.e., the system gives processed-information on the presence of enemies and the risk for allies),

147   and decision assistance (i.e., the system provides a recommendation on the best decision to make).

148   In our study, SoA is measured both at the implicit level, using the Intentional Binding paradigm,

149   and at the explicit level through a subjective assessment of responsibility (using an ad-hoc scale).

150   We also measured performance by using reaction time, the proportion of trials in which

151   participants chose to attack, and the proportion of choices leading to the fewest ally losses (called

152   *utilitarian choices* in our task).

153   The primary purpose of this research was to develop and test a new paradigm to investigate

154   how the interaction with autonomous systems can affect the SoA and the decisions made by people

155   when facing moral choices, and how the level of autonomy of the system influences this effect.

156   Based on previous findings (Berberian at al., 2012, Coyle et al., 2012; Zanatto et al., 2021), we

157   hypothesized that agency decreases with increasing levels of system autonomy, as indicated by a

158   longer time estimation between action and outcome, and lower subjective judgments of

159   responsibility at higher levels of system autonomy. We also hypothesized that if the SoA would

160   be affected by the autonomous system, as well as the sense of responsibility associated with SoA,

161   the moral decision-making would also be affected, with the number of attacks increasing as system

162   autonomy increases (Caspar et al., 2018; Goh et al., 2005, Chavaillaz et al., 2018). In addition, we

163   expected shorter reaction times and more utilitarian choices with higher levels of system

164   autonomy. Crucially, by validating the new paradigm we propose with the present study, we hope

165   to pave the way for new quantitative studies to understand how the interaction with autonomous

166   systems affects agency and decision- making in a moral context. In turn, understanding these

167   effects better could help in the development of safer and more efficient autonomous systems in the

168   future.

2. Method

2.1. Participants

A total of 31 participants took part in the study (M_{age} = 22, SD = 2.28, Range = 19 – 36, 7 women, 24 men). Participants were cadets at the Royal Military Academy of Belgium and were recruited with the help of a Master student officer in the course of his thesis. Participants were in their third and fourth year of study, meaning they had notions of International Humanitarian Law, and thus about what is legally allowed and forbidden in the conduct of armed conflicts. The sample size was estimated using G*Power (Faul, Erdfelder, Lang, & Buchner, 2007), with a small-to-medium size effect f of 0.2, a threshold for significance α set at 0.05, and a power 1-β at .80. Based on these values, the estimated sample size was 28 participants. To compensate for potential data losses and exclusions, a total of 32 participants was targeted. However, considering the limited pool and recruitment period, 31 participants were finally included in this study. The study was performed in accordance with the principles expressed in the declaration of Helsinki and with the protocol of the local ethics review board at the Faculty of Psychology and Educational Sciences at Ghent University. Participants were informed of the general purpose and the duration of the experiment, and about their rights as participants in psychological research before giving their consent. Participation was voluntary and participants could withdraw their participation at any time without justification and without consequences. Written informed consent was obtained from each participant before the experiment.

2.2. Stimuli and procedure

All the material can be found on the Open Science Framework (Salatino et al., 2023). The experiment was programmed and presented using MATLAB 2020b and the Psychophysics

192　Toolbox extension. The experiment was run on a laptop computer (display resolution: 2560*1600

193　pixels) and responses were collected via an AZERTY keyboard with left and right arrow keys

194　serving as the response keys used in the experiment. The experiment was conducted in an

195　experimental room in the department of Life Sciences at the Royal Military Academy. Participants

196　were seated on a chair, in front of a table with the screen of the laptop being at approximately 40

197　cm from the participants. Each trial of the task consisted of a 50 by 50 grid with dark grey cells

198　(RGB = [064, 064, 064]) presented on a black screen (RGB = [000, 000, 000]; see Fig. 1, below).

199　Participants were instructed that the grid represented a radar display used to inform on the position

200　of allies and enemies. Out of the 2500 cells, 100 were colored in light grey (RGB = [192, 192,

201　192]) and each light grey cell represented the position of a group of 10 allies. The number of allied

202　forces (i.e., light grey cells) was kept constant across trials, but their position varied randomly from

203　trials to trials. In addition, in 66% of trials one of the 2500 cells was colored in white (RGB = [255,

204　255, 255]) to represent the presence and the position of an enemy. Maximum one cell was colored

205　in white during trials (i.e., maximum of one enemy). When an enemy (i.e., a white cell) was

206　presented on a trial, participants were asked to choose between attacking the enemy or not by

207　pushing the left (attack) and right (no attack) arrows of the keyboard (i.e., Action 1- A1, if they

208　decide to attack, and Action 2- A2, if they decide to not attack). Participants were instructed that

209　not pushing the "attack" button whenever an enemy was present would result in the death of five

210　allies because of the continued hostile activities of that enemy. Instead, pushing the "attack" button

211　whenever an enemy was present would result in the death of the enemy, but with sometimes a risk

212　of collateral damages considering the position of the allies on the 50 by 50 grid radar display (see

213　details in the next paragraph below). Collateral damage was likely, but not sure, when grey cells

214   were separated from the enemy by less than five empty cells. When no enemy was shown on the

215   grid, participants were asked to not push on the "attack" button.

216

217   *Fig. 1, here*

218

219   During the experiment, participants were tested on three different types of trials,

220   representing three levels of Uncertainty: *No Risk* trials, *No Enemy* trials, and *Moral Decision-*

221   *Making (Moral DM)* trials. In the *No Risk trials*, an enemy was shown on the radar display and

222   allies were separated from five cells of more from the enemy, meaning there were no risk of

223   collateral damage. In the *No Enemy trials*, no enemy was shown on the radar display. Finally, in

224   *Moral DM trials* an enemy was shown on the radar display and up to three groups of allies were

225   on the first to the fifth range of cells next to the enemy. Here, participants received the instruction

226   that during those trials there was a risk of collateral damages if they decided to attack. More

227   exactly, participants were instructed that allies found on the 1st range of cells next to the position

228   of the enemy had a .50 probability of being killed if they decided to attack, while the probability

229   of collateral damages decreased with the distance according to the following *range – probability*

230   combinations: 2nd range – .40, 3rd range – .30, 4th range – .20, and 5th range – .10. The number of

231   allies that could be killed during an attack varied from 10, 20, or 30 allies. Groups of allies were

232   systematically on the same range of cells and *Moral DM* trials consisted in 15 different *number of*

233   *allies* by *probabilities of collateral damages* combinations. Thus, we expected those trials to be

234   morally challenging because participants were asked to choose between (1) pushing the attack

235   button to neutralize the enemy, but with the risk of killing allies during the attack, or (2) not

236   pushing the attack button and let the enemy kill 5 allies anyway.

237   The experiment consisted of three blocks, with each block including a specific level of

238   Autonomy from intelligent system (*Level 0*, *Level 1*, *Level 2*). In *Level 0*, the block with the lowest

239   level of assistance from intelligent system, participants received basic visual assistance to

240   determine the position of allies relatively to the position of an enemy shown on the grid. During

241   *No Risk* and *Moral DM* trials, by clicking with the help of the computer mouse on a white cell

242   while the 50 by 50 grid was shown on the screen, the cells on the 6th range next to the position of

243   the enemy turned blue (RGB = [000, 000, 255]) until the participants made their decision. This

244   visual information was designed to help the participants to detect how far allied forces were from

245   the enemy's position and to compute the risk of collateral damages if they decided to press the

246   attack button. However, allies found within that area were at risk for collateral damages, with the

247   risk depending on the range.

248   Then, in *Level 1* of Autonomy, in addition to the basic visual assistance found in *Level 0*,

249   a 12 grade-scale was shown on the right part of the screen (see Fig. 1, right up) participants were

250   instructed that this scale indicated the risk in terms of losses of allied forces if the attack button

251   was pressed. The risk was computed based on the number of allies within the blue area (i.e., 10,

252   20, or 30) and the probability of collateral damages based on their position (i.e., .50, .40, .30, .20,

253   or .10). The scale ranged from yellow (very low risk) to red (very high risk).

254   Finally, in *Level 2* of Autonomy, the visual assistance of *Level 0* was still included, but in

255   addition participants were assisted by a decision-support system that on each trial made a yes/no

256   recommendation on the best decision to make (see Fig. 1, right bottom). This recommendation was

257   based in each trial on the choice associated with the lowest expected losses in terms of allied forces.

258   When the expected losses were lower for pressing the attack button the 'yes' cue was highlighted,

259   while the 'no' cue was highlighted when the expected losses were lower by pressing the no attack

260   button (except during the trial where the number of allies was 10 and the probability was .50, in

261   which expected losses were equal for both choice). Participants were not informed on the

262   computation on which the recommendations were determined. Overall, each block consisted of 15

263   *No Risk* trials, 15 *No Enemy* trials, and 15 *Moral DM* trials.

264   The experimental setup of this task is shown in Fig. 1 (left): (1) First a loading bar was

265   presented for delay chosen randomly between 1000ms and 2000ms to signal a new trial to the

266   participants. (2) This was followed by a blackout screen for 500ms and then the presentation of

267   the 50 by 50 grid, displayed for 15000ms or until the participant pressed one of the two response

268   keys. (3) Participants were asked to confirm their choice by pressing the selected response key

269   again, or they had the possibility to change their choice by pressing the other key. (4) Responses

270   were followed by the presentation of blackout screen for a random duration of either 200, 500, or

271   800ms, and a tone (frequency: 400Hz) for 200ms. Finally, (5) participants were asked to report the

272   duration of the interval between their confirmation choice and the tone on a horizontal scale

273   ranging from 0 ms to 1000 ms. Trials were separated by an interval of 1000ms.

274

275   *2.3. Measurements and analysis*

276   We used five dependent variables in this study: Decision, Utilitarian Choice, Response

277   Time, Agency, and Subjective Responsibility. Decision (A1) was expressed by the proportion of

278   trials on which participants decided to attack. Utilitarian Choice (UC) was expressed by the

279   proportion of choices implying the lowest expected losses (in percentage). Response Time (RT)

280   was the mean response time (in seconds) on each trial. SoA was measured by Intentional Binding

281   (IB, in milliseconds). IB was computed by subtracting each interval estimate from the mean actual

282   response-tone interval (500ms) and averaged these scores for each Uncertainty X Autonomy

283   condition. Each block of Autonomy ended with a subjective judgment of responsibility (SubjA),

284   in which participants were asked to indicate how much they felt responsible of the decisions they

285   made on a scale from -100 (not responsible at all) to 100 (entirely responsible)[1].

286   Statistical analyses were performed using JASP version 0.17.2. We performed separate

287   repeated-measures ANOVAs for A1, UC, RT, and IB with Uncertainty (*No Risk trials*, *No Enemy*

288   *trials*, *Moral Decision-Making trials*) and Autonomy (*Level 0*, *Level 1*, *Level 2*) as within-subject

289   factors. In addition, SubjA was compared by means of a repeated measures ANOVA with

290   Autonomy as within-subject factors. For each dependent variable, only data of participants within

291   +/- 2.5 SDs were considered. Greenhouse-Geisser correction was applied where sphericity was

292   violated. We assessed Moral decision-making by several indicators.

293   The primary focus of our analysis concerned the presence of a main effect of Uncertainty

294   on 1) A1, for which we expected a higher percentage of attacks during No Risk trials and a lower

295   percentage during no Enemy trials, 2) UC, for which we expected an increased number in the No

296   Risk and No Enemy (control) trials compared to the Moral Decision-Making trials, and 3) RT,

297   with expected shorter response time in the No Risk and No Enemy trials compared to the Moral

298   Decision-Making trials. These effects were expected to provide evidence of the moral conflict

299   produced by the scenarios. Regarding IB, following the results of Moretto et al. (2011), we

300   expected a main effect of Uncertainty with shorter time interval, indicating an increase of SoA,

301   during *Moral Decision-Making* trials in comparison with the two control trials. We also expected

302   a main effect of Autonomy on 1) UC, with an increased rate of UC with the level of autonomy of

303   the task, 2) RT, congruent with the main effect of Uncertainty, 3) IB, with less IB, indicating a

304   decrease of SoA, with increased level of autonomy in line with the conclusions of Berberian et al.

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[1] This range is commonly used in human contingency assessment (for recent examples, see Prével et al., 2021 or Vaghi et al., 2019).

305   (2012), and 4) SubjA, with lower SubjA with increased level of autonomy. These effects were

306   expected to provide evidence of the effectiveness of the paradigm we developed. The threshold

307   selected for significance was $p < .05$ with a two-tailed approach. Raw data, scripts, and processed

308   data can be found on the Open Science Framework (Salatino et al., 2023).

309

310

3. Results

3.1. Analyses on A1 decisions

The analysis on A1 decisions (i.e. the proportion of attacks) (Fig. 2) revealed a main effect of Uncertainty ($F_{(1.06, 27.72)} = 926.70$, $p < .001$, $\eta p2 = .97$) and post hoc tests showed that all comparisons were significant (all $ps < .001$) with more a1 choices during *No Risk* trials (mean = 99.48, SEM = .20) in comparison with *Moral DM* trials (mean = 54.24, SEM = 1.77) and *No Enemy* trials (mean = .81, SEM = .52). However, the analysis revealed no significant effect of Autonomy ($F_{(1.78, 46.39)} = 2.80$, $p = .07$, $\eta p2 = .09$) on A1, as well as no significant interaction between Uncertainty and Autonomy ($F_{(2.76, 71.98)} = 1.17$, $p = .32$, $\eta p2 = .04$).

3.2. Analyses on Utilitarian Choice (UC)

The analysis on UC (i.e., the choices implying the lowest expected losses, Fig. 3, Panel A) revealed a significant effect of Uncertainty ($F_{(1.18, 31.96)} = 95.76$, $p < .001$, $\eta p2 = .78$). Post hoc tests showed a significant difference between *Moral DM* trials (mean = 84.02, SEM = 1.09) and *No Risk* trials (mean = 99.30, SEM = 0.27), and between *Moral DM* and *No Enemy* trials (mean = 99.21, SEM =.50) (all $ps < .001$), with a reduced number of UC during *Moral DM* trials, but not between *No Risk* and *No Enemy* trials ($p = 1.000$). The analysis (Fig. 3, Panel B) also revealed a significant effect of Autonomy ($F_{(1.76, 47.55)} = 8.67$, $p < .001$, $\eta p2 = .24$). Post hoc tests showed no significant difference between *Level 0* (mean = 94.10, SEM = 1.07) and *Level 1* (mean = 92.59, SEM = 1.17) ($p = .17$) and between *Level 0* and *Level 2* (mean = 95.84, SEM = .88) ($p = .089$). A significant difference was found in the proportion of UC between *Level 1* and *Level 2* ($p < .001$) with more UC on *Level 2*. Finally, the analysis revealed no significant interaction between Uncertainty and Autonomy ($F_{(2.36, 63.80)} = 2.48$, $p = .08$, $\eta p2 = .08$).

334

335   *3.3. Analyses on Response Time (RT)*

336   The analysis on RT (Fig. 4, Panel A) revealed a significant effect of Uncertainty ($F_{(1.73,}$

337    $_{46.95)}$ = 68.76, p < .001, $\eta p2$ = .71) with post hoc tests showing that all comparisons were

338   significant (all ps ≤ 0.36), with longer RT during *Moral DM* trials (mean = 4.62, SEM = .20) than

339   during *No Risk* (mean = 2.27, SEM = .12) and *No Enemy* trials (mean = 2.82, SEM = .14). In

340   addition, the analysis revealed no significant effect of Autonomy ($F_{(1.68, 45.36)}$ = 0.667, p = .49,

341    $\eta p2$ = .02), but a significant interaction (Fig. 4, Panel B) between Uncertainty and Autonomy (F

342    $_{(3.43, 92.74)}$ = 3.81, p = .009, $\eta p2$ = .12), with a simple main effect of Autonomy in *No Enemy*

343   trials (p = 0.03), but not in other Uncertainty conditions (all p > .37).

344

345   *3.4. Analyses on Intentional Binding (IB)*

346   The analysis on IB (Fig. 5) revealed a significant effect of Uncertainty ($F_{(1.56, 46.87)}$ =

347   8.12, p = .002, $\eta p2$ = .21) with post hoc tests showing a significant difference between *Moral DM*

348   trials (mean = 118.85, SEM = 13.58) and *No Risk* trials (mean = 147.04, SEM = 13.99) and

349   between *Moral DM* and *No Enemy* trials (mean = 145.53, SEM = 13.69) (all p < 0.005), with

350   shorter intervals reported in *No Risk* and *No Enemy trials* in comparison with *Moral Decision-*

351   *Making* trials. No significant differences were found between *No Risk* and *No Enemy* trials (p =

352   1.000). Concerning Autonomy, the analysis revealed no significant effect ($F_{(1.76, 52.82)}$ = 0.67,

353   p = .495, $\eta p2$ = .022) and no significant interaction between Uncertainty and Autonomy ($F_{(3.52,}$

354    $_{105.86)}$ = 1.29, p = .27, $\eta p2$ = .04).

355

356   *3.5 Analyses of subjective judgment of responsibility (SubjAs)*

357   The analysis on SubjAs (i.e., how much participants felt responsible of the decisions made,

358   Fig. 6) revealed a significant effect of Autonomy (F $(1.61, 45.15) = 15.72$, p < .001, ηp2 = .36).

359   Post hoc tests showed a significant difference between *Level 0* (mean = 84.13, SEM = 3.04) and

360   *Level 1* (mean = 71.72, SEM = 4.60) (p = .006) and between *Level 0* and *Level 2* (mean = 58.62,

361   SEM = 69) (p < .001), with larger subjective responsibility rating during *Level 0* in both cases, but

362   not between *Level 1* and *Level 2* (p = .065).

363

364

365 **4. Discussion**

366   In the present pilot study, we aimed to develop a new paradigm to investigate how the sense

367 of agency and (moral) decision-making are influenced by the type of input received from an

368 intelligent autonomous system. To this end, we programmed a task in which participants, in the

369 role of drone operators, had to decide whether (or not) to initiate an attack on a simulated

370 battlefield, during different trial types and with the support of an intelligent system at three levels

371 of autonomy. Ultimately, the overall goal of this research agenda was to develop a paradigm to

372 investigate the mechanisms involved in human-AI interactions in the context of morally

373 challenging situations and to better understand the determining factors in the effect of (inputs

374 received from) autonomous systems on the decisions of human agents faced with moral choices.

375   Our results show that our new paradigm was sensitive enough to discriminate between

376 moral and non-moral situations. Indeed, participants in our study had a .54 likelihood to initiate an

377 attack in our moral situations, while they refrained from attacking when there were no enemies,

378 and systematically attacked in situations where an enemy was present, but an attack posed no risk

379 for allied troops. Furthermore, the moral situations were characterized by less utilitarian choices

380 than our control condition, reflecting the uncertainty of the situation. Notably, the assistance of the

381 autonomous system increased the number of utilitarian choices, demonstrating the influence of the

382 machine on decision-making. Finally, the moral situations were characterized by a longer reaction

383 time, indicating the participants' hesitation when they had to decide to fire or to not fire when

384 allies' life were at stake. Thus, this pilot study thus provides a preliminary paradigm for

385 investigating research questions related to the effects of human-machine interactions in moral

386 decision-making situations.

387   Our results were partially consistent with our expectations, as the number of attacks

388   increased when there was no risk and decreased when there was no enemy, confirming that our

389   control trials were working properly as well. However, no effects related to the level of autonomy

390   were found regarding the proportion of attacks. One possibility is that human choices, when made

391   in the context of moral dilemmas, are not influenced by the level of autonomy of a system, contrary

392   to choices made in a context without these dilemmas. However, this would be surprising, given

393   that previous studies conducted in military scenarios (e.g., Chen & Joyner, 2009; Rovira et al.,

394   2007) have found an influence of the level of autonomy on human performance and decision.

395   Another interpretation for the lack of an effect of level of autonomy on the rate of A1 choices relies

396   on the way the task was designed (and in particular the possibility for participants to calculate

397   maybe too easily the expected losses for both alternatives in each choice), resulting in ceiling/floor

398   effects in the control conditions and an A1 rate of around 50% during *Moral Decision-Making*

399   trials.

400   With respect to the Utilitarian Choice, i.e., the proportion of choices that lead to the least

401   loss of allies, we expected an increase in UC in trials without moral conflict and an effect of

402   autonomy leading to an increase in these choices at the highest level of Autonomy (as evidence of

403   an effect of autonomous system on moral decision). Our results confirmed our expectations, with

404   utilitarian choices increasing as a function of Uncertainty and Autonomy. Considering that the

405   recommendations made with the highest level of system support were based on the lower expected

406   losses computed, our results showed that our participants' moral choices were significantly

407   changed by the input received from the system. This suggests that human choices can be influenced

408   by the recommendations received from a decision support system, independently of the morally-

409   unmorally challenging nature of the situation.

410   In relation to the Response Time, we expected that participants would take a longer time

411   to make a decision on trials with a moral conflict and Autonomy would shorten participants'

412   response times. Our results confirmed our expectation, with RTs being longer in moral situations,

413   suggesting that participants took longer to make a decision when a moral conflict was present, and

414   that the highest level of system support shortened their response time in the No-Enemy trials. This

415   last result is consistent with previous findings from laboratory experiments showing that

416   autonomous systems can help users in detection tasks (e.g., Goh et al., 2005), although it is

417   surprising that this effect was found only for the absence of target but not for the presence of target

418   during trials without risk, which is somehow inconsistent with previous findings (e.g., Chavaillaz

419   et al., 2018). One possible reason for this result could be that the target used in our task (i.e., a

420   white square among grey squares on a black background) was too noticeable and thus too easy to

421   recognize for the *Level 1* and *Level 2* functions to be useful to participants.

422   Regarding SoA, given that a decrease in agency in human-machine interactions has been

423   previously reported (Berberian et al., 2012; Vantrepotte et al., 2022), we firstly expected that

424   participants would show a decrease in the Intentional Binding and subjective sense of

425   responsibility at higher levels of support, indicating a decrease in the SoA. Consistent with our

426   hypothesis, our results showed a decrease in the SoA at the explicit level with higher levels of

427   support. This result is also consistent with the recently described human tendency to attribute moral

428   responsibility to non-human agents which may lead people to be willing to blame them (Furlough,

429   et al., 2021; Kneer and Stuart, 2021; Liu and Du, 2022). Nevertheless, our results did not show a

430   decrease in SoA at the implicit level, which is inconsistent with our expectations and previous

431   studies (Berberian et al., 2012). However, this discrepancy is not completely surprising

432   considering that a dissociation between the two levels of measures in the SoA has already been

433   reported in previous studies (e.g., Synofzik et al., 2008; Moore and Obhi, 2012; Saito et al., 2015).

434   It has been suggested that at the explicit level a higher-order conceptual judgement of being an

435   agent is formed and that this aspect of SoA is closely related to higher-level sources of information

436   such as social and contextual cues (Synofzik et al., 2008), suggesting that Intentional Binding and

437   explicit judgments of agency do not share the same processes (Dewey & Knoblich, 2014). Since

438   the two measurement systems are separable (Saito et al., 2015), it is possible that dissociation

439   between implicit and explicit measurements occurred in our study. In particular, in our new

440   paradigm the three autonomy conditions may not have been so different as to yield a significant

441   difference at the implicit level of agency, but only at the explicit level.

442   Still regarding SoA, consistent with previous findings (Moretto et al., 2011), we also

443   expected an increase in SoA during Moral Decision-Making trials. Consequently, we expected that

444   moral decision making would also be affected. Because SoA appears to be closely related to moral

445   responsibility (Moretto et al., 2011; Caspar, et al., 2016) and this is reduced by the level of

446   autonomy of the machine, we expected that a decrease in the sense of responsibility would lead to

447   a change in the number of attacks at the highest level of system autonomy. However, contrary to

448   our expectations, the results showed a significant decrease in the SoA in the *Moral Decision-*

449   *Making* trials at the implicit level (i.e., in the IB). One possible explanation for these results is

450   related to the human tendency to take more responsibility for positive than for negative events,

451   which seems to be a mechanism for increasing self-esteem (Bradley, 1978; Greenberg et al., 1992;

452   Yoshie and Haggard, 2013). However, it has been pointed out there is a tendency to overestimate

453   one's agency, and that this bias is stronger when the outcome of an action is positive rather than

454   neutral or negative (Wegner & Wheatley, 1999; Haggard, 2017). Because the risk of a potential

455   hit to allies was constantly present in the Moral Decision-Making trials in our task, it is possible

456   that participants in these trials had a reduced SoA and responsibility, and disengaged from the

457   situation due to the risk of negative dramatic consequences of their actions. ‑Alternatively, it is

458   also possible that these results are related to the young cadets' lower SoA, which has already been

459   described by Caspar and colleagues (Caspar et al., 2018). However, these results should be taken

460   with caution, considering a flaw in the preparation of the Matlab script used to run the experiment,

461   and the possibility that the time intervals used for the time estimations (200, 500, and 800ms) were

462   not completely assigned equally across Uncertainty conditions (i.e., that each time interval are

463   shown five times per Uncertainty condition). Indeed, the program was designed to generate for

464   each three blocks (corresponding to the three levels of Autonomy) 15 presentations of each interval

465   duration (45 intervals in total) presented in a random order across trials (45 trials/block). Albeit

466   randomly presented across Uncertainty conditions, it is possible that the number of presentations

467   of each interval duration was not perfectly the same across Uncertainty condition. Future

468   investigations will be therefore necessary to determine whether the SoA decreases when human

469   subjects interact with autonomous systems when making moral decisions compared to situations

470   that do not pose a moral challenge, or whether this result is due to the methodological flaw

471   observed in our experiment.

472   To summarize, our results show that human choices made in morally-challenging scenarios

473   can be differentially influenced by the recommendations received from different level of

474   autonomous systems, replicating and extending previous findings (e.g., Chen & Joyner, 2009;

475   Rovira et al., 2007 for studies in the military domain). This was measured by the small but

476   significant difference in the number of utilitarian choices between conditions and the decrement

477   in response time in the No Enemy trials. Interestingly, this effect was completed by a decrement

478   in the subjective measure of agency with higher levels of autonomy, which is consistent with

479   previous research (Barberian et al., 2012; Vantrepotte et al., 2022). At the same time, however,

480   our results show some inconsistencies with previous studies (Moretto et al., 2011; Berberian et al.,

481   2012), with less agency measured in the moral decision-Making trials and no significant difference

482   across Level of Autonomy at the implicit level of agency (IB). Thus, further experiments need to

483   be conducted to determine if the inconsistent results we found were related to the design of the

484   experiment as we suggested above. In particular, in addition to the change need on the Intentional

485   Binding measure, the scenario we used was closer to impersonal/neutral stimuli rather than a

486   moral/emotional context. For example, the radar screen shown to participants was quite schematic

487   and likely did not allow participants to properly imagine the context of the choices they were

488   making. In addition, they did not know the number of victims following their decision, and the

489   victims were not clearly shown as individuals. Thus, it could be that the images we used did not

490   have enough emotional content to reinforce/enhance the SoA. Since the sense of agency could be

491   also affected by the actions' outcome, which is missing in the current version of the task, to

492   overcome this issue, future research could improve our paradigm by using a less neutral task and

493   content with more moral and emotional valence.

494

495   **5. Conclusion**

496   Considering the increasing presence of intelligent autonomous systems in our daily lives, it is

497   crucial to conduct further research to better understand the implications in sensitive domains such

498   as the military context to provide input for the successful design of innovative automated systems.

499   Our findings suggest that the level of system autonomy influences participants' moral decision-

500   making and that input received from an intelligent autonomous system influences SoA. By

501   developing a valid paradigm for assessing the impact of human-machine interaction on moral

502   decision-making in the military, with the present study we pave the way for further lines of

503   research on the influence of autonomous systems on human moral behavior, considering the

504   current lack of research on this issue.

505

506

507 **Author contributions: A.P., S.L.B., E.C.**: Conceptualization, Methodology. **A.P.**: Software.

508 **A.S., A.P.**: Investigation. **A.S., A.P.**: Data curation, Formal Analysis, Writing- Original draft

509 preparation. **E.C., S.L.B.**: Supervision. **S.L.B.**: Funding acquisition. **A.S., A.P., E.C., S.L.B.**:

510 Writing- Reviewing and Editing.

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780   **Fig. 1.**
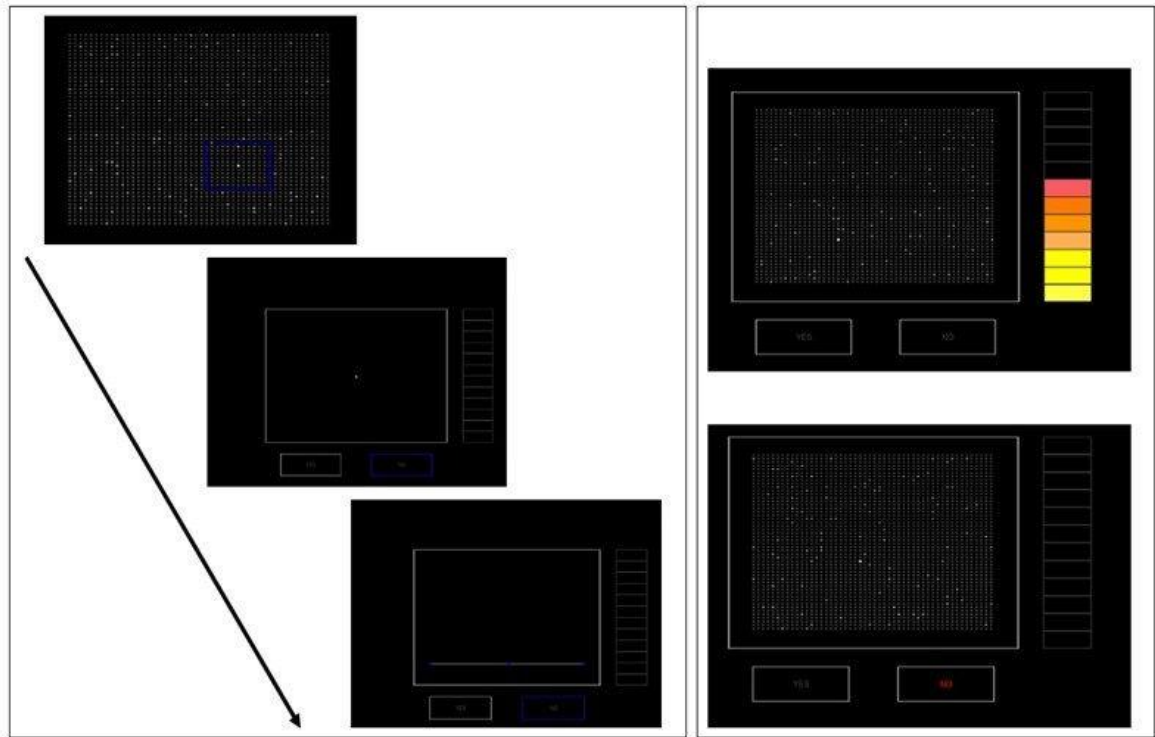
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782   **Fig. 1. Experimental setup.** Each trial of the task consisted of a 50 x 50 grid of dark grey
783   cells on a black screen (**Left Panel**), representing a radar display informing of the position
784   of allies and enemies. Of the 2500 cells, 100 were colored light grey and represented the
785   position of a group of 10 allies, which varied in position from trial to trial.
786   In 66% of the trials, one of the 2500 cells was coloured white to represent an enemy and
787   participants were asked to choose whether or not to attack the enemy by pressing the left
788   (attack) or right (no attack) arrow key on the keyboard. The grid was displayed for 15000ms
789   or until the participant pressed one of the two response keys. After the response, a blackout
790   screen was displayed for a random duration (200, 500 or 800ms) and a tone (200ms).
791   Participants were asked to indicate the duration of the interval between their choice and the
792   tone on a horizontal scale from 0 ms to 1000 ms. *Level 1* of system autonomy is shown in
793   the right panel (**top**), where in addition to the basic visual assistance of *Level 0*, a scale has
794   been displayed indicating the risk in terms of losses of allied forces in the event of an attack.
795   In *Level 2* (**Lower Right Panel**), in addition to the visual assistance of *Level 0*, participants
796   were assisted by a decision support system that gave a yes/no recommendation for the best
797   decision to make.

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802   **Fig. 2.**

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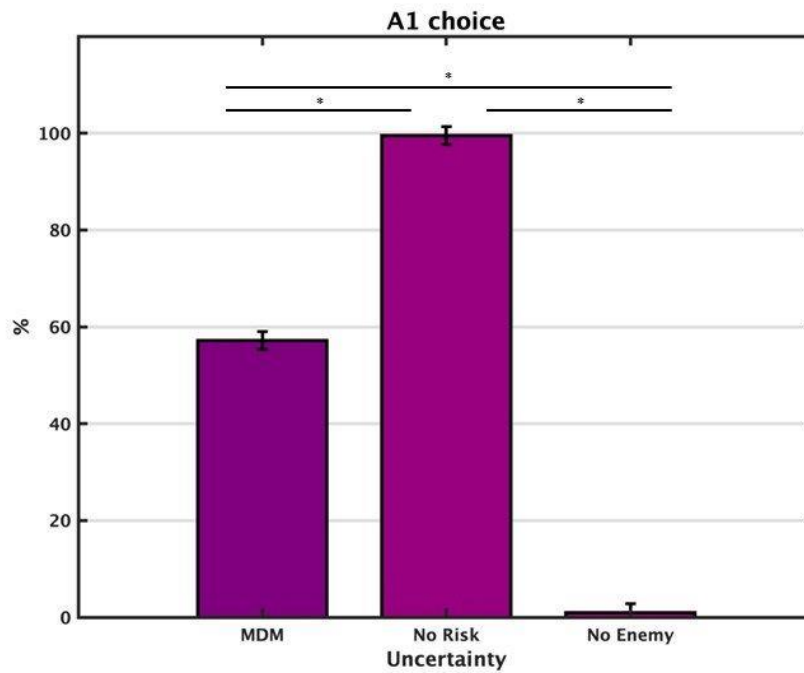
804   **Fig. 2. Proportion of A1 action (i.e. attacks performed).** A significant increase of A1
805   choices during *No Risk* trials in comparison with *Moral Decision-Making* and *No Enemy*
806   trials were found (all $p < .001$). * = significant.
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816   **Fig. 3.**
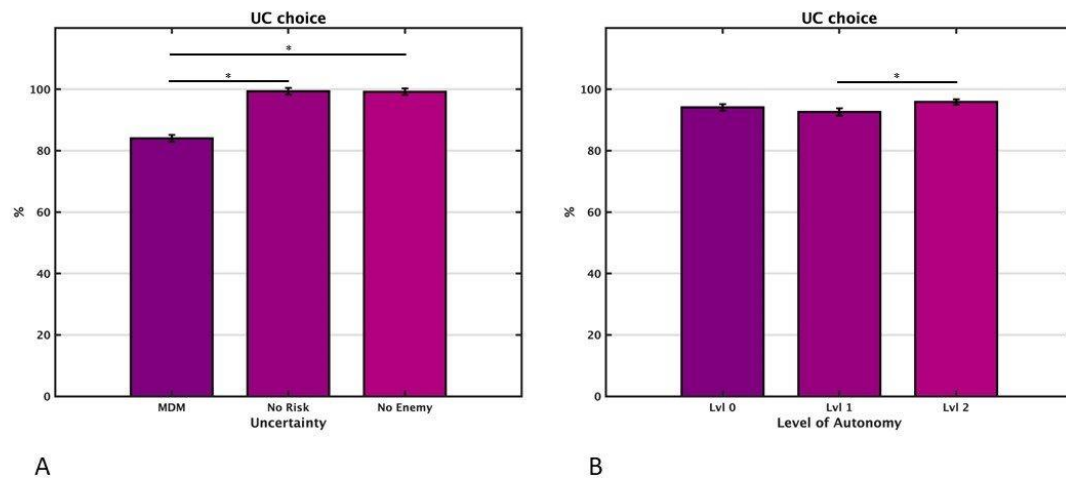
817

818   **Fig. 3. Proportion of UC (i.e. Utilitarian Choices).** A significant difference was found in
819   UC between *Moral Decision-Making* trials and *No Risk trials*, and between *Moral*
820   *Decision-Making* and *No Enemy* trials (all p < .001), with a reduced number of UC during
821   *Moral Decision-Making* trials, but not between *No Risk* and *No Enemy* trials (**Panel A**). A
822   significant difference was found in the proportion of UC between *Level 1* and *Level 2* (p <
823   .001) with more UC on *Level 2*. * = significant.
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826 **Fig. 4.**
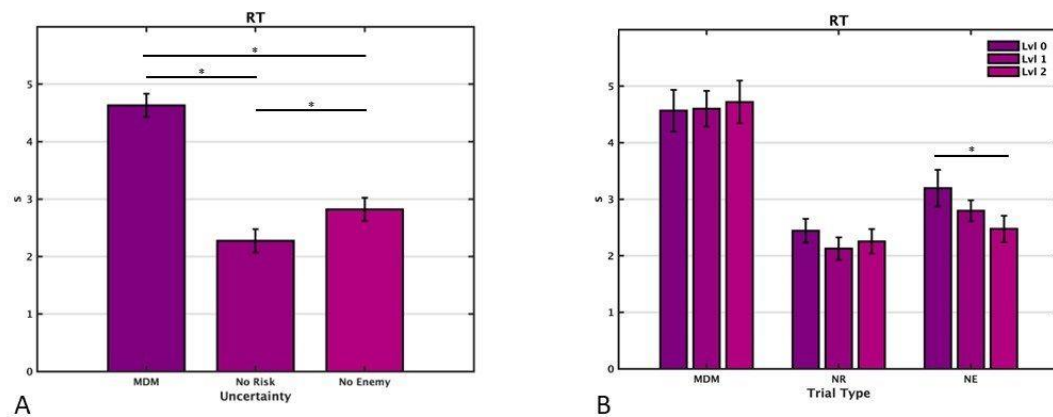
827

828 **Fig. 4. Response time (in seconds).** A significant increase in the RT was found during
829 *Moral Decision-Making trials* compared to the *No Risk* and *No Enemy trials* were found
830 (all $p < 0.36$, **Panel A**). In addition, a significant ($p = .009$) interaction was found between
831 Uncertainty and Autonomy (**Panel B**), with a simple main effect of Autonomy in *No Enemy*
832 *trials* ($p = 0.03$). * = significant.

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837   **Fig. 5.**
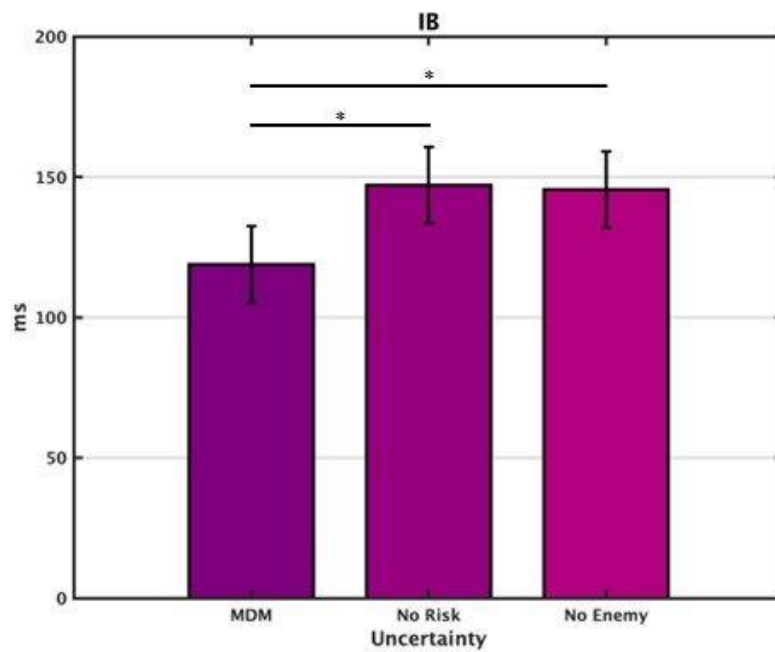
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839   **Fig. 5. Intentional binding (IB).** A significant difference in the IB was found between
840   *Moral Decision-Making trials* and *No Risk trials*, and between *Moral Decision-Making*
841   *trials* and *No Enemy trials* (all $p < 0.005$), with shorter intervals reported in *No Risk* and
842   *No Enemy trials* compared to the *Moral Decision-Making trials*. * = significant.
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853   **Fig. 6.**
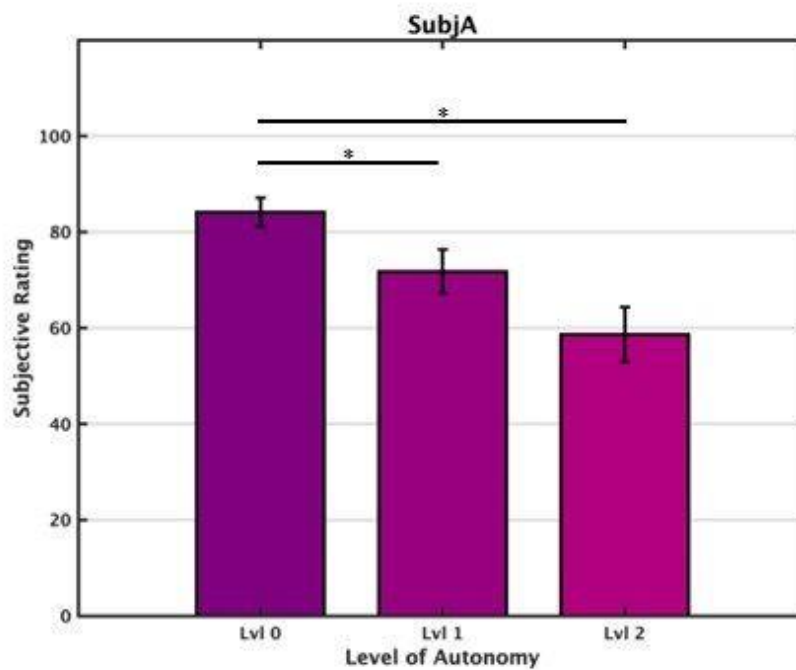
854

855   **Fig. 6. Subjective assessment of responsibility**. A significant decrease in subjective
856   judgement of responsibility was found in *Level 0* compared to *Level 1* (p = .006) and in
857   *Level 0* compared to *Level 2* (p <.001), with greater subjective judgement of responsibility
858   in *Level 0* compared to *Level 1* and *Level 2*. * = significant.
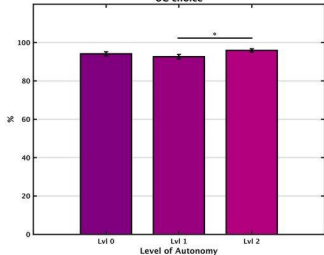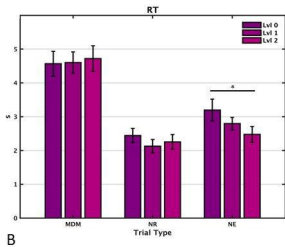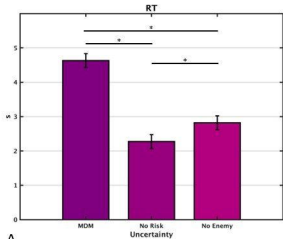859

860

A1 choice

A

B

A

B

SubjA