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1 **Promoting fertility awareness and preconception health using a chatbot: A randomized**
2 **controlled trial**

3

4 **Short title:**

5 Chatbot for fertility awareness

6

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Abstract

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Research Question: What are the effects of using a fertility education chatbot (i.e., automatic conversation program) on knowledge, intentions to improve preconception behaviour, and anxiety?

Design: A three-armed, randomized, controlled trial was conducted using an online social research panel. Participants included 927 women aged 20–34 years who were randomly allocated to one of three groups: a fertility education chatbot (intervention group, IG), a document about fertility and preconception health (control group 1, CG1), or a document about an irrelevant topic (control group 2, CG2). Participants' scores on the Cardiff Fertility Knowledge Scale and the State-Trait Anxiety Inventory, their intentions to optimise preconception behaviours (e.g., taking folic acid), and the free-text feedback provided by chatbot users were assessed.

Results: A repeated-measures analysis of variance showed significant fertility knowledge gains after the intervention in the IG (+9.1 points) and CG1 (+14.9 points) but no significant change in CG2 (+1.1 points). Post-test increases in the intentions to optimise behaviours were significantly higher in the IG than in CG2 and were similar to those in CG1. Post-test state anxiety scores were significantly lower in the IG than in CG1 and CG2. User feedbacks about the chatbot suggested technical limitations (e.g., low comprehension of users' words) and pros and cons of using the chatbot (e.g., convenient versus coldness).

Conclusions: Providing fertility education using a chatbot improved fertility knowledge and intentions to optimise preconception behaviour without increasing anxiety, but the improvement in knowledge was small. Further technical development and exploration of personal affinity for technology is required.

Keywords: fertility awareness, education, preconception, chatbot, digital technology

Introduction

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Fertility awareness is of growing interest and importance in the world (Zegers-Hochschild et al., 2017). Many people postpone parenthood due to career, education, relationship, and financial issues (Mills et al., 2011); as a result, people sometimes face biological barriers to achieving a desired family size (Habbema et al., 2015). In addition to choices, an increased incidence of non-communicable diseases such as obesity, diabetes, and thyroid disorders (Broughton and Moley, 2017; Thong et al., 2020; Krassas et al., 2010) has caused more women of reproductive age to experience subfertility. In such contexts, fertility education is provided to reproductive-aged people in the community, schools, and health care facilities using various tools, such as brochures, online information, theatre, and educational videos (Daniluk and Koert, 2013; Hvidman et al., 2014; Hammarberg et al., 2013; Boivin et al., 2018a; Harper et al., 2019). These educational interventions improve fertility awareness, both in the short term (Daniluk and Koert, 2015; Wojcieszek and Thompson., 2013; Maeda et al., 2016) and even two years after exposure (Maeda et al., 2018). However, interest in future pregnancy and fertility education is often limited, as is the ability to integrate fertility information into everyday life (Boivin et al., 2018b; Maeda et al., 2018). It is therefore necessary to continue developing strategies to encourage people to participate in their fertility, particularly strategies that can be delivered efficiently to large populations.

Maintaining good preconception health helps ensure successful pregnancies, healthy babies, and good health in the current and next generation (World Health Organization, 2012; Stephenson et al., 2018). Preconception health promotion encourages all reproductive-aged people, irrespective of their current childbearing intentions, to achieve optimal health and wellness, thus ensuring good health for them and any children they may have (Verbiest et al.,

67 2016). Preconception care can include reproductive life plan (RLP) counselling; provision of
68 family planning and contraception; guidance about nutrition, immunizations, infection control,
69 and treatment and monitoring of chronic medical conditions; and information about exposure-
70 related lifestyle choices, such as tobacco and alcohol use and substance abuse (Malnory and
71 Johnson, 2010; Jack et al., 2008).

72 In Japan, where the total fertility rate is low (1.42 in 2018) and the parental age at first birth
73 is high (30.7 and 32.8 years for women and men, respectively, in 2018), awareness of
74 preconception health seems to be as low as awareness of fertility (Maeda et al., 2015). For
75 example, the main contraceptive method in Japan is condoms (83%), which have a typical use
76 failure rate that is reported to be much higher than that of hormonal methods (13% versus 0.01 to
77 7%) (Trussell et al., 2018). In addition, very few women (3%) take oral contraceptive pills,
78 despite the obvious reproductive benefits (Yoshida et al., 2016). Once pregnant, only 8% of
79 women in Japan use folic acid supplementation adequately (Ishikawa et al., 2018). Evidence
80 suggests that mental models of pregnancy interfere with preconception health practices. For
81 example, folic acid is believed to not be needed because of perceptions that the good health of
82 the mother protects the pregnancy from threat or that pregnancy has evolved to be naturally
83 robust or immune to risk (Fulford et al. 2014). Promoting knowledge of and involvement with
84 preconception health tackles misconceptions arising from mental models, and it thus seems to be
85 as essential as fertility education among people of reproductive age.

86 Novel digital technology can be used to deliver low-cost health promotion initiatives at the
87 population level, particularly among those of reproductive age. These digital natives include
88 Millennials born in 1980–1994 and iGen born in 1995 or later (Twenge, 2017). Indeed, mobile
89 health apps, such as *Smarter Pregnancy* (van Dijk et al., 2017) and *Infotility* (Zelkowitz et al.,

90 2019), and virtual animated characters, such as Gabby (Jack et al., 2015), have shown promising
91 results for improving preconception health. The chatting robot, or “chatbot,” may also be useful
92 in this context. A chatbot is an information and communication tool that uses natural language
93 processing to interact with users automatically (Schmidlen et al., 2019). The chatbot can be
94 programmed with scripts that provide tailored information to users, although most of these
95 scripts are limited to predetermined scenarios. Chatbots used in customer services and banking
96 industries have also been applied in health care contexts to provide education about sex, drugs,
97 and alcohol (Crutzen et al., 2011) and to screen patients for sexually transmitted infections
98 (Kobori et al., 2018). Thus, although still in its developmental phase, chatbot technology could
99 be a promising strategy for promoting fertility awareness and preconception care.

100 Previous research suggests that interaction and learning with a virtual agent may mitigate
101 negative emotions; people sometimes feel more comfortable sharing sensitive information with
102 computers, which they perceive to be safer confidantes than other people (Lucas et al., 2014;
103 Palanica et al., 2019). Also, Stein and Brooks (2017) reported that “compassionate” care
104 provided by a chatbot facilitates behavioural changes and weight loss among overweight and
105 obese participants. Previously, our randomized controlled trial showed that fertility education
106 using online brochures improves fertility knowledge, but it increases anxiety among people who
107 want to have a child (Maeda et al., 2016). Given that fertility information often involves private
108 lifestyle information, people may feel more comfortable receiving counselling and information
109 from a new technology than from conventional methods (e.g., brochures).

110 The aim of the present study was to evaluate whether a chatbot that provides fertility and
111 preconception health education changes the knowledge levels, health-related intentions, and
112 psychological states among reproductive-aged users. We specifically targeted women aged

113 between 20 and 34 years who were assumed to need correct fertility information and to be
114 familiar with digital technology. We randomised reproductive-aged participants into one of three
115 groups: an intervention group (IG), which interacted with an educational chatbot designed to
116 provide fertility and preconception health; a control group (CG1), which received a PDF
117 document about fertility and preconception health; or another control group (CG2), which
118 received a PDF document about an irrelevant topic, the national pension system. We
119 hypothesised that people in the IG would demonstrate a greater increase in knowledge and
120 intentions to optimise preconception lifestyles than those in the control groups. In addition, we
121 hypothesised that people in the IG would show less anxiety than those in the control groups.

122

123

Materials and Methods

124 We conducted a three-armed (one intervention and two control groups), randomized, open-label,
125 controlled trial in March 2019: Trial registration number: UMIN Clinical Trials Registry
126 (UMIN000035736). Participants were randomly assigned to one of three educational materials.

127

Ethical approval

128 The ethics committee at Akita University Graduate School of Medicine approved the study
129 protocol on March 29, 2018 (no. 1918).

130

Participants

131 Participants were recruited via an online social research panel. Inclusion criteria were being a
132 woman aged 20 to 34 years and hoping to have children (or more children) **now or in the future,**
133 **regardless of any current effort or plan to achieve pregnancy.** We excluded women who were
134 currently pregnant. Medical professionals were excluded from recruitment. By default,
135 advertising professionals were excluded from the online social research panel according to the

136 market research company procedures (see “Procedures”). Only those who voluntarily agreed to
137 spend about one hour learning the assigned material were invited to participate in the survey.

138 **Procedures**

139 An online market research company (Macromill, Tokyo, Japan), which has a nationwide social
140 research panel of more than 1 million registrants, sent a pre-screening questionnaire regarding
141 the inclusion criteria to 196,195 randomly selected female registrants aged 20–34 years. Of the
142 10,000 women who responded to the screening questions, 2,524 were eligible. Among the 1,813
143 who were randomly selected from the eligible respondents and received recruitment emails, 927
144 completed the survey (51.1% participation rate among eligible invitees). Participants were then
145 randomized to one of the three previously described groups (for each group, $n = 309$) using a
146 computerized central allocation system (ScreeningMacro, Macromill, Japan). Participants did not
147 learn of their group assignment until they completed the post-test survey. Figure 1 illustrates the
148 participant selection and randomization process.

149 All study materials were presented online using Airs software (Macromill). After completing
150 the pre-test survey, participants received instructions for their assigned group. Participants in the
151 IG were instructed to go to a website and chat with the online chatbot. Participants in CG1 and
152 CG2 were instructed to visit a website and read the entire online brochure at the respective site.
153 Then, participants were asked to close the study website and complete a post-test survey. Those
154 who completed the survey were given a coupon, which was consistent with the market research
155 company’s procedures (usually less than 1 Euro). All procedures were conducted from March 13,
156 2019, to March 22, 2019.

157 **Educational materials**

158 We developed a scripted chatbot for the IG (Figure 2). Scripted chatbots generally involve a
159 predetermined scenario wherein the chatbot responds to the user's input with appropriate, pre-
160 determined information. For our predetermined scenario, we programmed the chatbot to start by
161 asking questions we adapted from RLP counselling and education (Malnory and Johnson, 2010).
162 Specifically, the chatbot's information was excerpted from an educational booklet for general
163 readers by the Japan Society of Obstetrics and Gynecology (2018). Topics included factors with
164 significant impacts on fertility and preconception health: normal and abnormal menstruation;
165 timing of sex to increase the likelihood of pregnancy; infertility (definition, prevalence, causes
166 among men and women, and age-related declines); contraception; abortion; sexually transmitted
167 and other types of infections; common reproductive diseases in young women (fibroids and
168 endometriosis); chronic diseases (e.g., depression and diabetes); other diseases (breast and
169 cervical cancers); appropriate body weight for a safe pregnancy; harmful lifestyle choices, such
170 as smoking, alcohol, and illegal drug consumption; vaccinations; domestic violence; and sexual
171 diversity. The contents and text expressions were simplified and summarized to accommodate
172 the chatting style.

173 To design the chatbot conversations in line with the RLP counselling style (Stern et al.,
174 2013), we consulted several educational sources, including Habbema et al. (2015) and *A Guide to*
175 *Fertility* by Boivin (2018a; Cardiff Fertility Studies Research Group, 2016). We drew a flowchart
176 with 8,931 characters in Japanese. The expected conversations were implemented using Google
177 Cloud's Dialogflow, a natural language processing engine. In addition, we appended as many
178 potential phrases and keywords as possible from users and chatbot responses. Prototypes were
179 repeatedly tested and refined, first internally and then by a small group of university students and

180 colleagues at collaborative companies, until the chatbot development team comprising
181 researchers, information technology experts, and designers was satisfied with the response
182 functions and the quality.

183 Participants in CG1 were provided with a PDF document containing the same fertility and
184 preconception health information as in the chatbot (Japan Society of Obstetrics and Gynecology,
185 2018). The PDF comprised 43 pages and 42,070 Japanese characters. Participants in CG2 were
186 provided with a PDF document containing information about the national pension system (a
187 topic unrelated to fertility education), which was excerpted from the Ministry of Health, Labour,
188 and Welfare (2017a) website. The PDF comprised 34 pages and 26,233 Japanese characters. We
189 conducted a pilot survey with a small group of our colleagues to ensure that the PDFs and
190 questionnaire were understandable.

191 **Measures**

192 *Fertility knowledge*

193 We used the Japanese version of the Cardiff Fertility Knowledge Scale (CFKS-J) (Bunting et al.,
194 2013; Maeda et al., 2015) to assess fertility knowledge on the pre- and post-test surveys as a
195 primary outcome. The CFKS-J uses 13 items to measure knowledge about fertility facts, risks,
196 and myths. All items were rated as 'true', 'false', or 'do not know'. A correct answer received
197 one point, and an incorrect or 'do not know' answer received zero points. Scores were reported
198 as the percentage of correct answers (0% to 100%). The internal consistency coefficient alpha of
199 the CFKS-J was 0.74, and the scale had a one-factor structure (Maeda et al., 2015).

200 *Preconception health status, behaviour, and intention to change*

201 For the pre-test survey, participants completed a questionnaire about the following health status
202 items: weight (kg), height (cm), severe period pain (yes/no), and presence of abnormal menstrual

203 cycle length (less than 21 days, more than 35 days, irregular, or amenorrhoea) without oral
204 contraceptives (Bunting and Boivin, 2010). Participants also reported on the following behaviour
205 related to their fertility and preconception health; the answers in bold letter were assumed to be
206 preconception behaviours: 1) current smoker (**yes/no**), 2) proactive intake of folic acid
207 supplement or enriched food (**yes/no**), 3) vaccination against HPV infection (**yes/no**), 4) previous
208 cervical check-ups (**yes/no**), and 5) having a primary obstetrics and gynaecology (ob/gyn) doctor
209 (**yes/no**). In Japan, ob/gyn specialists, instead of general physicians, address all primary care for
210 ob/gyn diseases. In addition, we asked participants about 6) currently trying to get pregnant
211 (**yes/no**). For those who were not currently trying to get pregnant, we asked about 7) their use of
212 oral contraceptives (**yes/no**) and 8) other contraceptive methods (**always yes/no**).

213 In the pre- and post-test surveys, participants who did not exhibit any of the eight
214 preconception behaviours listed above were asked to score their intention to change each
215 behaviour using a three-point scale: ‘preparation’ (i.e., ready to take action), ‘contemplation’
216 (i.e., interested in changing behaviour but still ambivalent), and ‘precontemplation’ (i.e., not
217 interested in the behaviour). These answers were based on the transtheoretical model before
218 action (Prochaska and DiClemente, 1983).

219 ***Post-test psychological assessment***

220 The psychological assessment was administered once during the post-test survey. We used the
221 Japanese version of the State-Trait Anxiety Inventory (STAI) (Spielberger et al., 1970; Nakazato
222 and Mizuguchi, 1982). The STAI uses a 4-point Likert scale (range of 20–80) to measure 20
223 state-anxiety items (STAI-S), which indicate the current anxiety level, and 20 trait-anxiety items
224 (STAI-T), which indicate the characteristic (trait) anxiety level. Higher scores indicate greater
225 anxiety. The Japanese version of the STAI-S has shown high internal consistency (coefficient

226 alpha = 0.92), and the STAI-T has shown a test-retest reliability of 0.76 for 1 hour later and 0.71
227 for 3 months later (Nakazato and Mizuguchi, 1982).

228 *Sociodemographic factors*

229 The online market research company provided participant ages. Participants also reported their
230 annual household incomes, university education (yes/no), current marriage status (yes/no), and
231 whether they had a child (yes/no). Annual household income was categorized into four groups:
232 low (< 4 million Japanese Yen), moderate (4–5 million Yen), high (≥ 6 million Yen), and
233 unknown. At the time of the study, 1 US Dollar = 110 Japanese Yen.

234 *Text analysis*

235 We analysed the free-text feedback qualitatively. Two researchers (EM and AM) separately
236 interpreted, classified, and tallied feedback items by topic. First, each researcher reviewed
237 respondents' feedback and divided the comments into individual, single-meaning text fragments.
238 Second, each researcher grouped similar text fragments together. Both researchers then discussed
239 the shared meanings of each sorted group and classified them into the broadest, but still
240 meaningful, categories. To ensure rigor and consistency of interpretation of the feedback, the
241 researchers discussed any disagreements and reached consensus on all classifications.

242 **Statistical analyses**

243 We estimated the sample size of each group ($n = 309$) based on the assumption that the mean
244 post-test knowledge scores for the IG and CG1 would increase by 70 ± 23 and 64 ± 23 percent
245 correct scores, respectively, according to results from previous studies (Maeda et al., 2016;
246 Bunting et al., 2013), with 90% power and a significance level of 5%.

247 We performed all analyses on an intention-to-treat basis. We compared sociodemographic
248 factors, preconception health status, and behaviour between the groups using chi-square tests,

249 one-way analysis of variance (ANOVA), Kruskal-Wallis tests, and post hoc Bonferroni multiple
250 corrections according to the type and distribution of variables. To determine the knowledge
251 difference between groups and over time (pre-test and post-test), we performed a repeated-
252 measures, mixed-factorial, between-within ANOVA using conservative F-tests (Greenhouse-
253 Geisser correction) for the main effect of time and for interactions between groups (IG, CG1, and
254 CG2) and times (pre-test and post-test). Simple effects were used as follow-up tests. To explore
255 between-group differences in pre-test to post-test changes in intention to adopt preconception
256 behaviour, we compared pre–post differences for each person between groups using a
257 nonparametric, pairwise, multiple-comparison procedure following Kruskal–Wallis tests, or
258 Dunn’s test (Dinno, 2015). All analyses were performed using STATA14-MP (StataCorp LP,
259 College Station, TX, USA). A two-sided *P*-value of <0.05 was considered statistically
260 significant.

261

262 **Results**

263 **Background characteristics and group equivalence**

264 Table 1 shows the demographic characteristics of the 927 participants. Participants were about 29
265 years old, and more than 60% had a university education, which was higher than **the national**
266 **university enrolment ratio of 43% among female high school graduates in 2008 (Ministry of**
267 **Education, Culture, Sports, Science and Technology, 2008)**. Less than half were married, and
268 most had no children. Baseline sociodemographic status was well-balanced between groups.
269 Regarding preconception health status and behaviour, about 20% were underweight and 10%
270 were overweight or obese, which is similar to national statistics of 22% and 6%, respectively,
271 among women in their 20s (Ministry of Health, Labour, and Welfare, 2017b). More than half

272 reported severe period pains or abnormal menstrual cycles, but less than 30% had a primary
273 ob/gyn. Fewer than 20% of women reported taking proactive folic acid or receiving an HPV
274 vaccination. Among those who were not currently trying to get pregnant (81% of the
275 participants), 67% stated that they always used contraceptive methods and 9% reported using
276 oral contraceptives, which was a higher oral contraceptive use rate than that of a nationally
277 representative sample (3%) (Yoshida et al., 2016). Baseline health status and behaviours were
278 well-balanced between groups, although the proportion of participants having severe period pain
279 was significantly lower in CG1 than in the IG (Bonferroni adjusted $P = 0.03$).

280 **Effect of the intervention on outcomes**

281 We recorded 574 chatbot sessions, which had an average length of 8 minutes. Because the
282 chatbot was located on the private website during the survey period, multiple sessions were
283 recorded per participant.

284 ***Fertility knowledge***

285 The percentages of correct scores on the pre-test CFKS-J were similar between groups (mean \pm
286 SD was 59.5 ± 22.7 for the IG, 61.5 ± 20.6 for the CG1, and 60.9 ± 21.9 for the CG2; $P = 0.53$),
287 as shown in Figure 3A. A repeated-measures ANOVA of the scores on the CFKS-J showed a
288 significant interaction between group and time ($F [2, 924] = 51.1, P < 0.001$). Simple effects of
289 time for each group showed that knowledge improved over time in the IG (+9.1 points, 15%
290 gain, $P < 0.001$), CG1 (+14.9 points, 24% gain, $P < 0.001$), and CG2 (+1.1 points, 2% gain, $P =$
291 0.24). The post-test CFKS-J score for the IG (68.7 ± 23.0) was 7.7 points lower than that of CG1
292 ($76.4 \pm 18.4, P < 0.001$) and 6.7 points higher than that of CG2 ($62.0 \pm 23.6, P < 0.001$).

293 ***Intention to change preconception behaviour***

294 Participants who did not exhibit preventive behaviours on the pre-test survey scored their
295 intentions to change each behaviour before and after exposure to information in their respective
296 groups. As shown in Table 2, the pre-test to post-test increase of intentions to take folic acid, to
297 receive HPV vaccination, to obtain a primary ob/gyn, to take oral contraceptives, and to try to get
298 pregnant were significantly higher in the IG than in CG2. Compared with CG1, the increase in
299 the intention to take folic acid was significantly higher in the IG, whereas the intention to take
300 oral contraceptives was significantly lower in the IG. Even after considering the possible alpha
301 inflations for the family comparisons (i.e., eight behaviours) by applying additional Bonferroni
302 corrections, the results did not change except for the intention to try to get pregnant in the IG and
303 CG2.

304 ***Post-test psychological assessment***

305 Post-test state anxiety scores on the STAI (mean \pm SD) were significantly lower (less anxiety) in
306 the IG (43.2 ± 9.5) than in CG1 (47.5 ± 9.5) and CG2 (46.2 ± 9.0), all $P < 0.001$. No difference
307 in post-test trait anxiety scores existed between groups, indicating that differences in state
308 anxiety was not due to underlying differences in personality traits between groups (Figure 3B).

309 ***Feedback from chatbot users***

310 Of the 309 participants in the IG, 278 provided text feedback after the intervention (52 Japanese
311 characters, on average). Three topics were identified among the 275 specific comments,
312 including technical problems, pros and cons of using the chatbot, and experiences learning about
313 fertility and preconception health. Twenty-eight participants (10.2%) reported technical problems
314 (e.g., “It froze up soon” and “I could not chat at all”), and 77 (28.0%) mentioned low
315 comprehension of the chatbot (e.g., “I rephrased some words when the chatbot did not

316 *understand*” and *“There were problems of misunderstanding”*). Fifteen (5.5%) comments noted
317 that the chatbot operation was too slow, and another 14 (5.1%) reported that the information was
318 displayed too quickly.

319 Regarding the pros and cons of using the chatbot, 96 (34.9%) mentioned pros and 33 (12.0%)
320 mentioned cons. Benefits cited included that the experience was *“fun”*, *“interesting”*, *“easy”*,
321 *“convenient”*, *“casual”*, and *“did not make users feel embarrassment or shyness during chatting*
322 *about reproductive health ... because it is a chatbot”*. Among these positive comments, 28
323 (10.2%) indicated that learning through chatting could promote understanding more than just
324 reading. They mentioned that *“chatting style could lead to better understanding”* and that it was
325 *“easier to understand, compared to ordinary learning accompanied by reading long sentences”*.
326 On the other hand, 15 (5.5%) noted that chatting was burdensome and unnecessary. They
327 mentioned that *“reading good websites would be more impressive and readable than using*
328 *chatbot”* and that *“typing is burdensome”*. A lack of humanity or empathy (e.g., *“robotism”*,
329 *“coldness”*, or *“one-way interaction”*) was mentioned in 17 (6.2%) comments. Users *“felt like [I*
330 *was] being replied [to] automatically”* and that *“I was not treated with empathy”*. In terms of the
331 experience of learning about fertility and preconception health, 114 (41.5%) comments showed
332 appreciation for increased knowledge and awareness, but 30 (10.9%) stated that the content was
333 superficial or needed more details. One respondent noted that *“It was informative and helpful.*
334 *Although it would be sufficient for prior learning ... it would be better for those who are trying to*
335 *get pregnant to visit doctors for further information”*.

336

Discussion

337
338 In our study, users who learned through conversation with an educational chatbot increased their
339 fertility knowledge by 9 points (+15%) on the CFKS-J and had greater intentions to optimise
340 their preconception health behaviours. Although improvement of fertility knowledge was smaller
341 in the chatbot group (IG) than in the educational booklet group (CG1), the effects on behaviour
342 modification were equivalent between the two groups. Currently, fertility awareness depends on
343 different types of interventions – for example, from public health interventions delivered to many
344 people to personalised one-to-one counselling delivered to fewer (Hvidman et al., 2014; Stern et
345 al., 2013). In Japan, there are fertility awareness campaigns targeting young people (e.g.,
346 newlywed couples or those attending coming-of-age ceremonies) as well as clinics providing
347 preconception care. Consultation fees at these clinics are not covered by public health insurance,
348 however, and thus they involve extra expense for the people who use them. Our results suggest
349 that new digital technology can provide more options for fertility and preconception health
350 education delivered at the population level at a low cost. To improve knowledge of fertility
351 health among people of reproductive age, further technical development to enable smooth and
352 flexible communication is required.

353 The level of fertility knowledge improved considerably immediately after exposure to
354 fertility information in the IG and CG1 (Figure 3A). These results align with previous findings
355 that fertility knowledge consistently improves immediately after provision of information,
356 irrespective of educational strategy, such as web-based documents (Wojcieszek and Thompson,
357 2013; Daniluk and Koert, 2015; Boivin et al., 2018a), video (Conceição et al., 2017), and face-
358 to-face encounters (Garcia et al., 2016; Stern et al., 2013). Participants in the IG showed a 15%
359 increase in fertility knowledge from the pre-test to the post-test, compared with a 24% increase

360 in the CG1, in which participants received an in-depth booklet about female preconception
361 health. One explanation could be that some participants in the IG did not experience enough
362 conversation with the chatbot due to technical problems: the mean post-test scores of the 25
363 participants who reported insufficient exposure was 55 points, which was significantly lower
364 than the post-test scores of the rest of the IG (i.e., 70 points; data not shown). Technical
365 improvements to stabilize the chatbot system might further increase these knowledge gains.

366 Another explanation for the smaller-than-expected knowledge improvement in the IG could
367 be that the predetermined communication did not meet the needs of the participants, thus they
368 could not increase their knowledge. Although the scripted chatbot used natural language
369 processing to understand users' responses, whenever the conversation veered from the
370 predetermined scenarios, it responded, "*I'm sorry, I don't understand your question*". We could
371 not identify each user's transcripts or the timing of drop-out, but we speculate that some
372 participants in the IG might have given up on learning because they needed to follow all the
373 chatbot instructions and answer questions. In contrast, those in CG1 could have skipped
374 paragraphs in the PDF that contained information that they already knew, and focused only on
375 what they wanted and needed to learn. Instead of scripted chatbots, artificially intelligent
376 chatbots (Wall, 2018) could be built using big datasets (e.g., transcripts of patient-professional
377 conversations), which may provide more appropriate and tailored information to users.

378 Significantly lower state anxiety in the IG suggests suitability of the chatbot for fertility
379 awareness. We previously showed that provision of fertility information offers benefits of
380 increased knowledge but also induces anxiety (Maeda et al., 2016). We replicated these results in
381 the post-test anxiety scores of those in CG1 (Figure 3B). Yet, state anxiety in the IG was low,
382 despite the knowledge increase. The seemingly non-relevant information given to CG2 (i.e.,

383 national pension system) also might have provoked anxiety because the declining birth rate in
384 Japan could be a future threat to supporting an aging population (Nomura and Koizumi, 2016).
385 Still, the post-test anxiety level of the IG was similar and even lower than that of control groups
386 from a previous study (Maeda et al., 2016). One reason for low state anxiety in the IG could be
387 attributed to a smaller educational effect (+15% versus +24% in fertility knowledge); participants
388 in the IG did not learn enough to become stressed. However, the use of the chatbot itself might
389 have alleviated the psychological stress, as confirmed by the feedback describing the chatbot as
390 an easy, convenient, and casual tool that avoids embarrassment. Although further psychological
391 evaluation of specific conversation that could make people feel anxious (e.g., for women, age
392 they should start trying to conceive) is needed to determine if the chatbot achieved equivalent or
393 larger educational effects than other methods, educational interventions that do not provoke
394 anxiety can benefit users.

395 Online short education improved participants' intentions to participate in a wide range of
396 preconception behaviours (Table 2). Substantial literature shows that preconception education
397 and counselling improves maternal knowledge and behaviours, although effects on pregnancy
398 outcomes remain unclear (Hussein et al., 2016;; Barker et al., 2018). In Japan, some well-known
399 facts include the adverse effects of smoking, benefits of cervical check-ups, and the necessity of
400 contraception, as shown in the relatively high proportions of participants who exhibited those
401 behaviours compared with national statistics (Table 1). National statistics present similar data:
402 the smoking rate among women in their 20s and 30s is 6%–9% (Ministry of Health, Labour, and
403 Welfare, 2017b); the rate of biennial cervical check-ups is 42% (National Cancer Center of
404 Japan); and contraception rates among married and unmarried women are 46% and 87%,
405 respectively (National Institute of Population and Social Security Research, 2015). In this study,

406 we also confirmed that Japanese participants' knowledge of "unfamiliar" preventive behaviours
407 improved. Japan has low use rates of preconception folic acid (Ishikawa et al., 2018) and oral
408 contraceptive pills (Yoshida et al., 2016). Another prominent concern is the extremely low rate of
409 HPV vaccination (less than 1% among teenagers), likely because of a political change in 2013
410 that led to the suspension of proactive recommendations for the vaccine following intensive and
411 sensational media coverage of unconfirmed adverse events (Hanley et al., 2015). In light of these
412 health care challenges, our chatbot increased the percentage of participants who stated that they
413 were "ready to take action" regarding their intake of folic acid, use of oral contraceptives, HPV
414 vaccination status, and choice of primary ob/gyn doctor. **Indeed, we need to assess actual**
415 **behavioural changes through a follow-up study because knowledge is necessary but not always**
416 **sufficient to change behaviour; for example, people need to feel susceptible to problems before**
417 **they seek help (Fulford et al., 2013). However, a chatbot could at least** be a useful strategy for
418 promoting good health and preventing misunderstanding of health-related information in existing
419 materials and for addressing misconceptions arising from mental models of the robustness of
420 pregnancy (Fulford et al. 2014).

421 Recently, chatbots have been used in health care, such as teen health education (Crutzen et
422 al., 2011), sexually transmitted infection screening (Kobori et al., 2018), nurse training (Shorey
423 et al., 2019), chronic patient monitoring (Piau et al., 2019), genetic counselling (Schmidlen et al.,
424 2019), and post-examination care (Goldenthal et al., 2019). Most of these one-armed studies
425 assessed feasibility and reported positive feedback from users. Similar technology using virtual
426 characters has shown promising results. For example, researchers at Boston University
427 developed a virtual patient advocate named Gabby, who provides preconception health
428 information and education using verbal and nonverbal communication. Users can respond to

429 Gabby by selecting and clicking on the button best representing their own responses (Gardiner et
430 al., 2013). A six-month, randomized, controlled trial showed that preconception risk was lower
431 among the Gabby user group, compared with a control group that received a letter listing
432 personal health risks (Jack et al., 2015). In our randomized, controlled trial, a chatbot was
433 designed to promote proactive learning through free-text input instead of selecting options. The
434 results unexpectedly showed that although the chatbot produced significant knowledge gains,
435 these gains were inferior to those produced by well-written material on its own. Currently,
436 chatbot use in health education is limited, with diverse product specifications and study designs
437 (e.g., two-armed randomised controlled trials, cross-overs). Results from these studies will help
438 clarify the most effective specifications for using the technology (e.g., visual or auditory, concise
439 or detailed, passive or active).

440 Another important implication is the need to investigate personal affinity or preference
441 toward the use of technology. We found no moderation effects of sociodemographic factors (e.g.,
442 age, university education) or current pregnancy intention on knowledge increase of the
443 intervention (data not shown). The lack of humanity and empathy perceived by some users also
444 requires further engineering innovation. Notably, some participants reported that they preferred
445 the chatbot as a convenient and easy way to talk about sensitive topics, which accords with
446 previous studies suggesting that a virtual agent can alleviate negative feelings (Lucas et al., 2014;
447 Palanica et al., 2019). On the other hand, some users evaluated the chatbot as lacking humanity
448 or empathy. To improve this user experience and optimise the technology used in educational
449 settings, further testing should include Think Aloud protocols or cognitive interviewing while
450 interviewees are using the chatbot to access more deeply their thoughts about using the
451 technology.

452 This study has some limitations. First, the use of social research panels could have caused
453 selection bias associated with higher education (Haagen et al., 2003; Takahashi et al., 2011). In
454 this study, to encourage participants to take enough time to learn, we told participants beforehand
455 that the survey would include a one-hour learning session, which could have led to volunteer bias
456 toward people who were more educated and more interested in childbearing. In fact, the mean
457 pre-test knowledge score of the present participants was 61 points, which is equivalent to scores
458 found by international studies (Bunting et al., 2013; Boivin et al., 2018a) but much higher than
459 the average of 50 points found in Japan (Maeda et al., 2016). Also, the prevalence of participants
460 who reported taking folic acid and oral contraceptives was higher in our study than in previous
461 national data (Ishikawa et al., 2018; Yoshida et al., 2016). Second, although participants in all
462 groups were instructed to close the study website before proceeding to a post-test survey,
463 keeping the study material open was possible. The fact that participants in CG1 could have more
464 easily looked for the post-test answers than those in the IG might have led to measurement bias.
465 Third, the outcomes measured in this study were knowledge, intention, and psychological change
466 immediately after exposure **using mostly self-reported measurements**. Long-term evaluations of
467 hard outcomes (i.e., timing of first birth, actual behavioural change, and health of mothers and
468 children), **possibly accompanied with biomarkers for behaviour (e.g., cotinine measurement for**
469 **smoking status), could** be explored as benefits on these have been reported (Maeda et al., 2018).
470 Fourth, due to the costs of development, we could not create an educational chatbot for men or
471 all the people in this study. It is clear that information needs to be delivered to men as well.
472 Finally, this study was conducted in Japan using a social research panel, and thus responses to
473 fertility information and acceptance of digital technology might differ from those in other groups

474 or cultures. Cultural relevance to educational strategies and new technologies could be an area of
475 future research.

476 In conclusion, women who used an educational chatbot to learn about fertility and
477 preconception health significantly increased their fertility knowledge and modified their
478 intentions to optimise their preconception health immediately after exposure. However, the
479 improvement in fertility knowledge was smaller than that of participants who read a well-written
480 booklet, possibly because our chatbot had been in an early phase of development or because the
481 evaluation included methodological limitations such as selection bias. Nevertheless, the impact
482 on intentions and the finding that the chatbot did not provoke anxiety makes it a promising
483 educational strategy for application at the population level. Further technical development and
484 studies exploring personal affinity for technology in fertility awareness should be continued.

485

486

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494

Authors' Roles

495

496 EM contributed to the conception and design of the study; participated in the acquisition,
497 analyses, and interpretations of data; drafted all versions of the article; and approved the final
498 version for publication. AM contributed to the conception and design of the study, the analysis
499 and interpretation of data, all revisions, and the final approval for publication. JB and KN
500 contributed to the analysis and interpretation of data, all revisions, and the final approval for
501 publication. YK, HShirasawa, HSaito, and YT contributed to the conception and design of the
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503

Conflict of Interest

504

505 EM reports joint research funding from a public interest, the incorporated foundation *I More*
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