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# Identifying Which Relational Cues Users Find Helpful to Allow Tailoring of e-Coach Dialogues

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**Abstract:** Relational cues are extracts from actual verbal dialogues that help build the therapist–patient working alliance and stronger bond through the depiction of empathy, respect and openness. ECAs (Embodied conversational agents) are human-like virtual agents that exhibit verbal and non-verbal behaviours. In the digital health space, ECAs act as health coaches or experts. ECA dialogues have previously been designed to include relational cues to motivate patients to change their current behaviours and encourage adherence to a treatment plan. However, there is little understanding of who finds specific relational cues delivered by an ECA helpful or not. Drawing the literature together, we have categorised relational cues into empowering, working alliance, affirmative and social dialogue. In this study, we have embedded the dialogue of Alex, an ECA, to encourage healthy behaviours with all the relational cues (empathic Alex) or with none of the relational cues (neutral Alex). A total of 206 participants were randomly assigned to interact with either empathic or neutral Alex and were also asked to rate the helpfulness of selected relational cues. We explore if the perceived helpfulness of the relational cues is a good predictor of users’ intention to change the recommended health behaviours and/or development of a working alliance. Our models also investigate the impact of individual factors, including gender, age, culture and personality traits of the users. The idea is to establish whether a certain group of individuals having similarities in terms of individual factors found a particular cue or group of cues helpful. This will establish future versions of Alex and allow Alex to tailor its dialogue to specific groups, as well as help in building ECAs with multiple personalities and roles.



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## 1. Introduction

Embodied Conversational Agents (ECAs), which have both a visual virtual representation, typically human-like, as well as the ability to engage in a text-based interactive conversation with a human user, are increasingly being used in health applications. ECAs require socialisation traits and verbal and non-verbal responses that will motivate the user to build long-term relationship with the agent. ECAs have been studied across a diverse range of health programs, such as relational agents for anti-psychotic medication adherence [1], avatar-based health intervention to modify unhealthy lifestyles [2], exercise advisors that interact with older adults [3] and ECAs that can help cancer patients to adopt a positive lifestyle after chemotherapy [4]. Research has suggested frameworks to identify useful verbal behaviours for virtual agents, such as relational cues, including empathy, social dialogues and continuity [5] or the Big Five model of personality traits [6].

Bickmore and Cassell [7] identified a set of relational dialogue cues for designing dialogues in ECAs. A key motivation for these dialogue cues was to develop a working alliance between the ECA and the user [5]. A working alliance involves the development of shared goals, agreed tasks to achieve those goals and a sense of caring and trust [8] and has been found to be the strongest predictor of adherence to treatment advice [9,10].

Rojas-Barahona, Tseng, Dai, Mansfield, Ramadan, Ultes, Crawford and Gasic [11] used conversational agents who learned through deep learning to help patients with mental disorders, citing Bickmore's framework as the foundational rule-based dialogue system for machine learning that generated a more sophisticated dialogue corpus. Another ECA was proposed by Almohanna, Win and Meedyia [12], who aimed to provide post-delivery support for women in breastfeeding newborns, mentioning the framework of dialogue cues by Bickmore and Cassell [7] as a comprehensive solution for building computer-aided conversational agents. These and many other health-related works used Bickmore's relational cues to provide human-like empathic responses, making his work a sound and workable framework for dialogues. However, despite extensive exploration of relational cues [13], systematic inclusion or exclusion of specific relational cues and tailoring to certain users have rarely been explored.

Our work raises the question and seeks to answer whether different users expect different empathic responses based on their demographics, culture, social standing and pro-social behavioural inclination. Recent work by Ranjartabar, Richards, Bilgin and Kutay [14,15] to teach healthy study habits sought to determine if students found certain relational cues helpful. Using machine learning, the studies found that the classification of cues was greatly influenced by culture, level of study stress, subject chosen and other contextual information. Those findings inspire our work. Further, we build on other work using an e-Coach to encourage healthy behaviour change [16] that seeks to adapt the dialogue according to the user's motivation [16,17]. Those researchers offer a taxonomy of health topics to discuss [18] but do not consider how the dialogue should be delivered (i.e., what empathic/relational cues to include). We modify the dialogues of that e-Coach to include or exclude relational cues based on four main types of relational cues to determine which relational cues may be most helpful for different cohorts of users.

In this work, we draw the literature together on verbal cues in health coaching to identify four main verbal relational cues: empowerment; working alliance; affirmation; and social dialogue. We note that social dialogue has long been used by ECA researchers to build rapport, and there has been considerable interest in building a working alliance (shared goals and plans and trusting bond) between the ECA and human. Furthermore, previous work on empathic agents has employed affirmation strategies. ECAs that seek to deliver behaviour changes typically employ social chat, affirmation and a working alliance and often include persuasive strategies [19]. However, strategies that ensure that the ECA does not manipulate or nudge the user to behaviours without their understanding and informed consent by focusing on the empowerment of the user are less common. The novelty of our approach is not just a focus on empowerment and ethics, but also our long-term goal is to personalise the extent to which these four strategies are used. As a step in this direction, we evaluate users' responses to examples of each of these relational cues to understand which relational cues are preferred by which users in the two variants, one being the empathic and the other being the neutral. Our dialogues have been designed to support future automated inclusion/exclusion of the specific cues.

## 2. Further Background to Verbal Relational Cues

Asking caring questions and comforting the client/patient is a generic approach required in all empathic human interactions; the variation in terms of the verbiage of several cues, including self-disclosure and meta-relational cues, is dependent on the user's personality, current emotional state and context of interaction [20]. There are standard dialogue sets for greetings and farewells, and they follow the norms of a human-human interaction. Humour is not liked by many, and it has been considered irrelevant in some studies [21]. Bickmore and colleagues have identified the single most comprehensive set of relational cues for ECA dialogues, including Social Dialogue; Meta-Relational Dialogue; Empathic Feedback; Humour; Continuity behaviours; Self-Disclosure; Reference to mutual/sharing knowledge; Solidarity and rapport-mirroring; Politeness; and Inclusive pronouns [5]. These cues have been used in the design of numerous ECA dialogues. However, specific de-

scriptions of when certain cues should or should not be included or how certain users have responded to specific cues have not been elaborated. An exception is a work by Ranjartabar, Richards, Bilgin, Kutay and Mascarenhas [22], described in the introduction. That work has not explored the impact of specific cues on specific health behaviours or development of working alliance. For ECAs that seek to motivate the user to change their health behaviours a one size fits all approach that proposes use of such cues without specific understanding of what cues are useful to whom and when and for what purpose is unlikely to be appropriate or effective.

Drawing a large body of literature together, including Bickmore's 10 relational cues, we found many overlapping concepts and dialogue characteristics that could be grouped into four types: empowerment, working alliance, affirmation and social dialogue.

### 2.1. Empowerment and Health Coaching

According to Aloni [23], empowerment in healthcare is based on a philosophy of seeing the patient as an equal autonomous member of the healthcare team, in line with Freire's pedagogical ideas (a famous and progressive educationist in the late twentieth century, who believed that real learning happens when the learner is empowered to actively engage with real-world content). However, empowerment can be described in various ways, depending on the level of analysis: individual, organisational or community [24]. The ideal of equal patients with the right to participate in decisions about their own health requires tight cooperation between the patient and health professionals. Gibson [25] claims that empowerment can be defined as a social process of recognising, promoting and enhancing people's abilities to meet their own needs, solve their problems and mobilise the necessary resources to feel in control of their own lives. In a study by Tveiten and Knutsen [26], patient feedback was taken on their two sessions in which small talk followed by empowering dialogues were delivered to them. Some interesting feedback is mentioned below:

1. "Instead of only getting drugs, you get dialogue, understanding and empathy in addition to pain therapy. . ."
2. "They have to know everything to give the full benefit. If they don't allow me to tell all about myself, then they have no basis for helping me."

This shows the importance of understanding the user and targeting the dialogue with them.

### 2.2. Working Alliance

Researchers have concentrated on exploring the relationship between alliance and therapeutic outcome in a variety of contexts: different types of treatments, different populations and diagnostic categories, the effects of gender, and various factors related to the therapist [8]. Psychotherapy research has found that that alliance cannot be seen as a one-size-fits-all package. On the contrary, the nature of the alliance varies depending on the individual patient and therapist, a reality that has generated the proliferation of expressions such as "matching patients to therapies" [27] and "tailoring psychotherapies and therapists to patients" [28].

Results reported by Castonguay, Constantino and Holtforth [29] help identify important features of the therapeutic relationship/alliance from an empirically informed clinical point of view. If we focus on their findings related to dialogue used by the therapist, we note that certain types of interventions (e.g., inappropriate use of silence, inappropriate self-disclosure, rigidity, criticism, insistent use of transference interpretation) can cause or exacerbate difficulties and ruptures in the alliance.

The importance of the working alliance on coaching outcomes was confirmed in a review by Graßmann, Schölmerich and Schermuly [9]. A review of ECAs for behaviour changes also found that working alliance was a key driver in the design of numerous ECAs [30]. That review observed that much of the work on ECA social dialogue, empathic agents and the use of Bickmore's relational cues are driven by a primary focus on the bond

aspect of the working alliance. The review further noted the importance of addressing shared goals and mutual planning, which are consistent with the goals of empowerment and affirmation cues. Thus, our analysis evaluates the helpfulness of relational cues using the three components of a working alliance: shared goal, shared plan/tasks and bond [8].

### 2.3. Affirmation

Cameron, Mazer, DeLuca, Mohile and Epstein [31] recognise affirmation as ‘acknowledging something complex or otherwise emotionally challenging for the patient’ (p. 7). The complexity can be due to multiple reasons ranging from whether or not to take a medication to whether to follow a recommended treatment that is not fully understood. The main purpose of affirmation is to enable the patient to express their frustration openly. Letting the patient voice their concerns and respond in understandable utterances is the essence of affirmation.

Affirmation includes strategies such as encouragement and expression of empathy and understanding. Empathic ECAs have been designed and evaluated in multiple studies, but most studies have tended to focus on non-verbal expressions of empathy [32–34] via the ECA’s facial expressions and body gestures. Where there is an expression of both verbal and non-verbal empathy by ECAs, the approach often involves mirroring and letting the user know they were “heard”, as in the case of listening agents [35].

Affirmative dialogues have been associated with the intention of building a long-term working alliance in multiple clinical studies, including [36], where the challenges inherent in establishing and maintaining an alliance with suicidal patients from a psychodynamic point of view were addressed using the relevant concepts of validation, empathy, and genuine relatedness. This work stresses the importance of the patient’s experience of feeling understood and accepted despite the need for change. This tension between acceptance and change is central to the therapeutic alliance, and it can help the patient stay engaged in treatment despite the extreme affective intensity and interpersonal difficulties that may arise. In another study of psychodynamic therapy [37], Saunders examined the relationship bonding between the patient and the therapist through different alliance variables. Clients who felt motivated and invested in therapy and who rated the session as being affirmative were likely to rate the session as helpful and productive.

### 2.4. Social Dialogue Role in Motivational Coaching

Laver [38] defines social dialogues as language constructs that are mostly uttered during greetings and farewells. They build continuity in the conversation and contribute to ice-breaking during the conversation. They are specifically non-task-oriented and bring structure to the conversation with which humans psychologically become ready to open up and talk. In eHealth, dialogues that are about a patient’s current health status or previous medical history are called task-oriented. According to Laver [38], task-oriented dialogues can be divided into three phases of conversation: the opening, middle and closing phases. The purpose of the opening phase is to ease the transition from non-task-oriented communication to task-oriented communication and to increase the level of comfort during the conversation. This helps ‘break the ice’ before the task-oriented middle phase begins. Hence, the objective is to work around the reason for which the discussion is happening. In eHealth, the middle phase seeks to classify the level of the health issue and recommendation of the treatment. The closing phase again helps in transitioning from task-oriented communication to a comfortable finish. Social dialogues commonly play their role in the opening and ending phases.

According to Higashinaka, Dohsaka and Isozaki [39], conversational systems need to build trust or cultivate long-term relationships with users through social dialogues that include self-disclosure followed by empathic dialogues of agreement and disagreement with the disclosure. Social dialogues that exhibit self-disclosure and politeness are necessary for building trust. Self-disclosure is analysed in psychology, especially in the verbal and behavioural literature, for its ability to induce self-disclosure from the recipient, a

phenomenon known as reciprocity [40], whereby self-disclosure by one participant in a two-way social dialogue results in self-disclosure from the other participant in response. Both [41] analysed theories of socio-linguistic cues used in conversational analysis, such as emotion, sentiment, and dialogue acts, where politeness was established as a fundamental cue. Politeness is also a vital relational cue used in conversations that incur trust [42].

### 2.5. Research Questions

Based on the motivation behind dialogue enrichment using relational cues extracted from research, we pose the following three research questions (RQs) to guide the investigation of who finds which relational cues are helpful and the impact of helpful cues on working alliance and intention to change health behaviours.

- RQ1: Are there differences between the empathic or neutral groups in terms of which relational cues are found helpful?
- RQ2: Is there a relationship between the perceived helpfulness of specific (types of) relational cues and working alliance and/or change in behaviour?
- RQ3: Further to RQ2, what is the influence of individual factors, including age, gender and personality types?

## 3. Methodology

We conducted a pre-post experimental study to assess whether an empathic embodied conversational agent (empathic Alex) is better able to change the intention for certain health behaviours and/or build a better working alliance than the neutral one (neutral Alex) and to evaluate which relational cues, in particular, are found to be helpful. The dialogues were built after intensive research on relational cues that are considered vital in conversations led by digital as well as human coaches. The study was approved by our university Human Research Ethics Committee.

### 3.1. Recruitment

The voluntary study was advertised with numerous other studies via an online research participation portal at the host university. The portal is accessible to undergraduate students who belong to multiple subject areas, including psychology, computing, health sciences, business, arts and others. According to our ethics approval, participants should be 18 with no upper age limit. However, most commonly, students participating in the psychology pool studies are first-year students. Due to the egalitarian nature of Australian society, first-year students are not necessarily recent school leavers and will include mature-age students. After completion of the study, they receive course credit for their participation. During a recruitment period of 36 days, 217 students registered on the portal for this activity.

### 3.2. Materials

We created a digital coach called Alex. As we intend to use multiple coaches in future studies to assist the user in the future according to their different roles and expertise (e.g., dietician, general practitioner, physiotherapist), Alex was implemented using the COUCH architecture containing the WOOL dialogue engine, described further below. The design of the dialogue and user interaction are also described.

#### 3.2.1. COUCH and WOOL Platform

The council of coaches' basic architecture has three main components. The WOOL dialogue framework provides support to domain experts to author their dialogues. The Unity3D module helps build animations, and the ASAP Realizer module supports interaction between user input and the next move in the dialogue.

The conversation was displayed on the screen in text (see Figure 1 below) through a web-based front end, which is built on top of COUCH and handles the dialogue exchange through API calls built using Python and JSON utilities. After accessing the application

through a web-based interface, Alex first welcomes the user and introduces himself as a coach and the purpose of this session. After the introduction, the coaching session begins in which user moves through the conversation by making selections from different pre-built dialogue responses depending on whether the user understands and wants to move forward in the conversation or if the user needs more explanation or coaching to respond positively to Alex's suggestions. The sessions consist of a maximum of 36 interaction scenarios until the session ends.



**Figure 1.** Screenshot of interaction with Alex.

### 3.2.2. Coaching Strategy—Dialogue Creation

To create the dialogues, we adapted a coaching dialogue that had been previously implemented and evaluated using the COUCH architecture and WOOL language [17], described below, in which persuasion was used to build motivational dialogues. That persuasion approach first measured the motivation level in users and, based on that, either motivates them more or moves forward with healthy goal setting.

Our study enriches these persuasion dialogues with relational cues that have been used by other coaches to build a better-working alliance and increase the user's intention to change their behaviour based on the coach's social skill and level of empathy [43]. To identify the impact of relational cues on the user's intention to change their health behaviours and working alliance, we created two implementations of Alex, one with all relational cues (empathic Alex) and the other with neutral dialogue selections (neutral Alex). The helpfulness of a subset of the relational cues was rated by both user groups to allow us to measure the impact of specific types of relational cues.

As shown in Table 1, there are four types of cues described as follows. Empowerment dialogues encourage the patient to choose or to make a decision based on either giving options or clarifying consequences. Working alliance dialogue contributes to the mutual understanding towards the planning or execution of a certain task or goal and also contributes towards building an emotional bond between the patient and the coach. Affirmation dialogues confirm what the user has said, giving the impression of being listened to; express empathy, giving the impression that the listener understands how the user is feeling and provides encouragement that they are heading in the right direction. Social dialogues are non-task-based dialogues aimed to bring openness in the conversation by using greetings/farewells, reciprocal self-disclosure, politeness and sharing of personal experiences.

**Table 1.** Relational cue types with examples and distribution in dialogues.

Concept/Cue	Approach	Characteristics	Total Number of Cues
Empowerment (E)	Giving options, autonomous, consent	Choose, decide options	15
Working alliance (I)	Mutual understanding, shared goal and planning, working together	Inclusive pronoun, together, continuity	21
Affirmation (A)	Empathy, Encouragement and acknowledgement	Appreciation and Motivation	14
Social dialogue (S)	Things that are off-task, agent disclosing personal experiences and user self-disclosure	Reciprocal self-disclosure-me too, politeness, greetings/ farewells	23

Further clarifying the four types of cues, Table 1 summarises the strategies we used to realise each specific type of cue in our dialogues under “Approach” and common “characteristics” or features of the dialogue snippet with that embedded cue. As can be seen, there are multiple possible approaches and characteristics for each type of cue, and thus, multiple sentences/phrases need to be embedded in a dialogue to ensure each cue is included. In the dialogue designed for the study reported in this paper, we wrote multiple sentences/phrases for each of the four cues. For example, there were 15 sentences/phrases that provided options, choices and decision points to enable user control and realise the empowerment concept/cue. A total of 73 cues were included in our dialogue to cover the four types of cues. Since users select different options and take different paths, they will not experience all of the cues, but we have ensured a similar and balanced number of cues across all pathways.

The colours shown in Table 1 for each cue have been used to colour code the dialogue example provided for the “showing progress” dialogue group in Figure 2. The colour-coded parts without brackets show the empathic version, and the neutral version is shown colour-coded within the brackets ( ). For example, in the first dialogue snippet (shown as a row), Alex says, “I suggest I will regularly keep you updated on the progress that you (we) are making together”. The pronoun “We” is a relational cue commonly used in conversations for building working alliance by stressing that the user and coach are in this together. Hence, the word “together” is added at the end of the sentence. The neutral version replaces “we” with “you” and removes the word “together” since it places the responsibility of the progress entirely on the will and effort of the user. At the end of each dialogue snippet, the next state is indicated in double square brackets. The state name is shown at the start of each dialogue snippet. This indicates how the dialogue moves from one state to the next.

### 3.3. Procedure and Data Collection

The procedure for data collection is divided into three phases: pre-intervention, intervention and post-intervention. In the pre-intervention phase, the user completes demographic information including gender, age and cultural background; personality test; health behaviour questionnaire to provide a baseline of the recommended behaviours and to capture their level of knowledge about healthy activities.

The second phase of data collection is interaction with Alex, whereby the user goes through the coaching session with either empathic or neutral Alex, randomly selected by the Qualtrics research survey system. This interaction stores the duration, interaction screen information and the attempts made to access the app.

The third phase is the post-survey, where the user completes the same health behaviour questionnaire that was completed at baseline so we can measure whether the user is willing to change their behaviour. Finally, the participant answers questions about the working relationship with the agent, the usability of Alex and the helpfulness of selected relational cues. Each of the measures are described briefly below.

<p><b>Showing progress:</b> Alex: I suggest I will regularly keep you up to date on the progress that we (you) are making together. [[Continue]]</p>
<p>Continue Alex: I could, for example, say that every day I will provide you with some feedback on the number of steps that you've been walking, and how healthy you have been eating. [[How do you know how much I'm walking?   ElaborateStepCounting]] [[How do you know what I'm eating?   ElaborateFoodDiary]] ElaborateStepCounting Alex: Yes that's a good question! (Removed) I have automatic step counter for that (You have automatic step counters for that). If you agree to share (through sharing) this data, we (you) can keep track of your steps. But we'll (you can) figure that out when we (you) get there. [[Continue2]]</p>
<p>ElaborateFoodDiary Francois: Yes, that's a good question! (removed) I keep track in a food diary (You could keep track of that in a food diary). If you agree to maintain (Maintaining) a diary can be useful to log food choices but we'll (you can) figure that out when we (you) get there. [[Continue2]]</p>
<p>Continue2 Alex: I know you will be feeling (You will be) pushed in the beginning but by regularly checking in with your progress, I can encourage you to increase your set goals, or rather adjust them a little bit. [[Continue3]]</p>
<p>Continue3 Alex: Let's imagine you want to walk for 10 kilometres every week. I could then tell you every day how much you've already walked, and how far you still need to walk. As you tweak your (By tweaking) daily activities you get closer to your goal. Do you enjoy trying out new activities? (remove and adjust flow) [[Yes I do like adding variety to the daily routine.   Continue4]] [[No I don't like adding variety to the daily routine.   Continue4]]</p>
<p>Continue4 Francois: OK, if you decide to (if you) drink an additional 3 glasses of water every day, I can tell you how you're managing to do so over time "[[Okay, I think I understand?   EndStrategyStatement]]" "[[But, why is knowing this so important?   Elaborate]]"</p>
<p>EndStrategyStatement Francois: Great! I hope together we (you) can make progress towards becoming healthier).</p>
<p>Elaborate Alex: Insight! A healthy lifestyle starts with understanding your current behaviour. As a team effort, (remove) if I show you how you're doing, you can see how close you are to reaching your health goals. Then, it is up to you how much effort you can put in to (you can) make progress towards your goal. "[[Okay, I understand.   EndStrategyStatement]]"</p>

**Figure 2.** One of Alex's dialogues with color-coded relational cues (see Table 1). A user either receives the empathic version with relational cues or the neutral one with text inside the brackets.

### 3.3.1. Personality

The Ten-Item Personality Inventory (TIPI) is a brief assessment of the Big Five personality dimensions: (1) Extraversion, (2) Agreeableness, (3) Conscientiousness, (4) Emotional Stability, and (5) Openness to Experience. Items are rated on a scale from 1, strongly disagree, to 7, strongly agree. Example items include, "I see myself as extraverted, enthusiastic" (Extraversion) and "I see myself as dependable, self-disciplined" (Conscientiousness).

### 3.3.2. Behaviour Change Intention

In order to establish the change in motivation towards health behaviours discussed by Alex, intention to perform 8 health behaviours was asked pre-interaction with Alex and then post-interaction. Answers were given using a 5-point Likert scale (Never—1—to—Always—5).

The following persuasive features have been found to correlate with the motivation level of a user and are important in bringing about behaviour change [19]:

1. Self-goal setting feature includes defining a goal; setting an exercise goal, or setting a healthy eating goal.
2. Showing progress feature includes the use of step counter, logging food choices or tweaking a goal.
3. Implementation intention feature includes linking health activities to specific moments in time.



We have used these features to categorise and analyse the 8 health behaviours in our analyses.

### 3.3.3. Working Alliance Analysis—Session Rating Scale (SRS)

Working alliance between Alex and users was measured through the Session Rating Scale (SRS). The SRS uses four sliding scales from 0–10 with left and right markers: relationship scale—“I did not feel/felt heard, understood, and respected”; goal and topics scale—“We did not/did work on or talk about what I wanted to work on or talk about”; approach or method scale—“The therapist’s approach is not/is a good fit for me”; and overall “There was something missing in the session today/Overall, today’s session was right for me.” The SRS is scored by summing the four scores. Psychometric testing of the measure has identified a Cronbach’s alpha of 0.88 and reliability of 0.64 [44]. The measure has also been found to have a moderately strong correlation with the Working Alliance Inventory  $r = 0.63$  [45].

### 3.3.4. System Usability Scale (SUS)

The SUS [46] has been widely used and cited and become a de facto standard to measure the usability of products, services, hardware and software ranging from websites to desktop and mobile applications due to its simplicity and reliability, even on small samples [47]. The items consider ease of use, functional consistency, need for pre-training and willingness to use the system again. The instrument produces a score that can be used as a health check for the system, where a score of 80.3 or higher is considered an “A” and excellent, “people love your site and will recommend to friends”, and a score of 68.0 is defined as a “C” and “you are doing OK but could improve”. An SUS score above 68 would be considered above average, and anything below 68 is below average.

### 3.3.5. Helpfulness of the Relational Cues

The helpfulness of sixteen relational cues was measured on a 5-point Likert scale ranging from very unhelpful to very helpful. These cues are extractions from empathic Alex’s dialogues and include examples from each of the four types of relational cues: Empowering, Working Alliance, Affirmation and Social Dialogue. The users of neutral Alex were also asked to rate these extracts post Alex’s interaction to determine if perceived helpfulness is influenced by whether or not you have experienced the ECA using those cues. Examples of these cues are “I hope together we can make progress towards becoming healthier”, “If I don’t plan, I know I have the tendency to postpone things” and “If you set your own goal, chances are higher that you actually stick with them”.

The data have been collected in Qualtrics and stored in an Oracle Database for further querying. The data are analysed in statistical tools, including Excel data analysis utility and Python notebooks for advanced analytics.

Tests for normality were conducted to determine whether parametric or non-parametric tests were appropriate. The data were found to be normally distributed in the majority of cases; hence, we used *t*-test to determine significant differences in the means between neutral and empathic groups for behaviour change and working alliance. We used a significance level of 0.05.

Lastly, data were reviewed to determine whether different subgroups of the sample demonstrated different outcomes from participation in the intervention, especially keeping in view the individual factors of the user, including gender, age, personality traits and preference for helpfulness of all cues. Cues were analysed individually as well as in four groups of relational cues to establish patterns using predictive analytical methods of classification and regression. There were two different approaches for predictive change in intention; the eight behaviours were analysed using the predictive methods individually as well as in three groups according to the objective (goal setting, showing progress and implementation intention) this change fulfils. For working alliance, predictive analytics was used again to study the effects of relational cues and individual factors on SRS components.

The model that gave good accuracy on the validation set was identified as a determinant that relational cue likability impacted the working alliance score (Appendix B).

### 3.3.6. Predictions Based on Helpfulness of Relational Cues

To find the relationship between the individual factors: gender, age, personality and helpfulness of a certain cue and its effect on the change in intentions and also on working alliance, a pipeline of machine learning models was built. Models help in two ways: first, to measure the impact of relationship of each input variable with the target variable, and second, to determine the strength of that relationship through an evaluation matrix of accuracy.

In our models, the target variable is either change in intention for a specific health behaviour or prediction of working alliance. The target variable for change in health behaviour intention was coded as 0 for negative and no change in the participant's intention to do the behaviours, and 1 for positive changes (0 is classified for post interaction rating  $\leq 3$  and 1 for  $>3$ , where the rating range is 0–5). The working alliance target variable has a similar coding strategy (0 is coded for working alliance component rating  $\leq 3$  and 1 is coded for  $>3$ ).

Machine learning was used to identify the strength of association between relational cues helpfulness and intention to change behaviour (Appendix C). Binary logistic regression(s) and decision tree classifiers were used to produce two pipelines of models, the first one to explore the individual factors that can explain the variance in the intentions to change for the eight recommended health behaviours and then another one to study the effect of individual factors on working alliance components.

Binary logistic regression was run using the 'liblinear' solver in GridSearchCV method to extract the best classifier with a range of hyper-parameter testing and multi-fold cross-validation. The F-score is considered a standard measure of predictive performance, with scores in the range [0, 1] and higher representing better performance. The average F-score is 0.70, which means that the input variables have a strong relationship with the target variable, which is either change in behaviour intention or working alliance.

The individual factor's contribution is evaluated by building decision tree classifiers and analysing the features' importance score for each model. The higher the feature's importance, the stronger its relationship in predicting the target variable. For each model, the number of input variables is 31, as shown in Appendix A, and the inferences have been built on highest contributing variables set at 20, as shown in Appendix C, for one of the health behaviour's changes in intention and the details of model implementation are given in Appendix B for the same model.

Each relational cue is used as an independent factor in the first pipeline of models for change in intention and working alliance, resulting in 12 models (since there are 8 behaviours in the survey and four working alliance components in the SRS, resulting in 12 in total) in the first pipeline. Furthermore, these relational cues are grouped according to goal setting, showing progress and implementation intention category and then learned by the models in the second pipeline, which has the previous 12 models' target variables as explained in Appendix A and aggregated input features so as to generalise the relationship with the cues' category, and the likelihood of change in intention/working alliance in their respective models.

Working alliance is measured through SRS components: bond, task, goal and overall analysis of the user's experience with the agent, resulting in analysing four models with individual relational cues preference scores as independent variables and a dependent target variable for working alliance components. A single component's relationship is predicted in each model. Furthermore, relational cues' groupwise preference is studied with working alliance components, resulting in eight models in total for working alliance and individual factor's analysis.

## 4. Results

Out of the 217 users who were recruited, 206 users were able to interact with Alex and, hence, were eligible for further analysis. The eleven users who did not interact were not able to run WebGL in their browsers. Out of 206 users, 64% are psychology students, 2% are doing a computing major, 18% are health sciences, 5% are business, 7% are arts majors, and the remaining 5% are enrolled in other subjects. In total, 50% of these students were presented with empathic Alex and 50% were presented with neutral Alex to have an un-biased dataset for comparison, resulting in 103 participants in each group.

### 4.1. Demographic Analysis

Table 2 summarises the descriptive statistics for the empathic and neutral groups. In total, 66% of the users are females, and the mean age is 21. Analyses of the personality data found statistically significant differences between the empathic and neutral groups for Extroversion, Emotional Stability and Openness.

**Table 2.** Demographics by group.

Group	Empathic		Neutral		Combined		
Statistical test	N	%	N	%	N	%	
Male	30	15%	41	20%	71	34%	
Female	73	35%	62	30%	135	66%	
Oceania (Including Australia)	38	37%	52	50%	90	44%	
North-Western European	3	3%	4	4%	7	3%	
Southern-Eastern European	6	6%	5	5%	11	5%	
North African and Middle Eastern	11	11%	6	6%	17	8%	
South East Asian	13	13%	12	12%	25	12%	
North East Asian	1	1%	2	2%	3	1%	
Southern and Central Asian	10	10%	3	3%	13	6%	
People of the Americas	1	1%	3	3%	4	2%	
Sub-Saharan African	3	0%	2	0%	5	0%	
I don't identify with any cultural	2	3%	1	2%	3	2%	
I prefer not to answer	2	2%	1	1%	3	1%	
Group	Empathic		Neutral		Combined		<i>p</i> -value
Statistical test	Mean	s.d.	Mean	s.d.	Mean	s.d.	
Age	21.5	7.7	21.09	6.8	21.2	7.24	0.69
Extroversion	3.27	1.20	2.79	1.28	3.02	1.26	0.01
Agreeableness	2.68	1.25	2.78	1.13	2.72	1.19	0.56
Conscientiousness	3.77	1.06	3.52	1.09	3.64	1.07	0.10
Emotional Stability	2.33	1.14	2.78	1.12	2.55	1.14	0.01
Openness	2.36	1.13	2.78	1.12	2.56	1.14	0.01

### 4.2. Behaviour Change, Working Alliance and Usability

The focus of this paper is on participants' responses to the relational cues. While the results showed a significant increase in the intention to perform most of the behaviours after the intervention, this change was irrespective of the group. That is, the impact of relational cues was not evident from looking at the significant differences between pre- and post-means in both groups for the health behaviour change. Hence, further analyses have been performed, as mentioned in the next section. We also found no significant differences between the groups for the working alliance developed, with a mean SRS sum of 23.96 (s.d. 2.41) for empathic Alex and 24.18 (s.d. 2.48) for neutral Alex, independent *t*-test *p*-value = 0.69. From analyses of the SUS data, overall, there were no significant differences for the usability of empathic (mean = 2.94, s.d. 1.03) or neutral Alex (mean = 2.98, s.d. 1.04). However, the neutral group found the system significantly less complex ( $p = 0.008$ ), easier to use ( $p = 0.02$ ) and more confident using the system ( $p = 0.001$ ).

### 4.3. Helpfulness of Relational Cues

Firstly, we wanted to determine if there were any significant differences in the perceived helpfulness of the relational cues between the neutral or empathic groups. There was no obvious reason why there would be significant differences, except perhaps if having an agent deliver those cues influenced how they were perceived.

Table 3 shows that there were no significant differences for empowerment cues, whereas one affirmation cue and two working alliance and social dialogue cues were significantly different. For participants who interacted with neutral Alex, the preference was greater for the cues “But we’ll figure that out when we get there” and “If you set your own goal, chances are higher that you actually stick with them”. The unhelpfulness of certain cues was found to be less intense by the users of neutral Alex. Examples are “I can encourage you to increase our set goal” and “Yes that’s a good question!” Statistically, on average, 14% of empathic Alex users found the relational cues to be very helpful, and 54% found them helpful, 27% found them to be neither helpful nor unhelpful, and only 3% found them to be unhelpful. In the case of neutral Alex, the relational cues were not present in the coaching sessions; 24% of the users found them very helpful, and 41% found them helpful. In total, 26% found them neither helpful nor unhelpful, and 10% found them to be unhelpful.

**Table 3.** Relational cues rating count for helpful and very helpful by group.

<b>Empowerment</b>	<b>Emp</b>	<b>Neut</b>	<b>p-Val</b>	<b>M</b>	<b>F</b>	<b>p-Val</b>	<b>B</b>	<b>W</b>
I can encourage you to increase our set goals.	75	74	0.42	52	97	0.32	50	75
If you set your own goal, chances are higher that you actually stick with them.	78	82	0.80	53	107	0.53	25	25
If you agree to share this data, we can keep track of your steps.	65	66	0.65	42	89	0.34	25	25
If you decide to drink additional three glasses of water every day, I can tell you how you are managing to do so over time.	74	69	0.16	47	96	0.40	38	50
You can select different days of every week.	64	74	0.47	41	97	0.11	25	0
<b>Working Alliance</b>	<b>Emp</b>	<b>Neut</b>	<b>p-val</b>	<b>M</b>	<b>F</b>	<b>p-val</b>	<b>B</b>	<b>W</b>
As a team effort, if I show you how you’re doing, you can see how close you are to reaching your health goals.	70	76	0.35	46	100	0.17	25	25
I hope together we can make progress towards becoming healthier.	65	61	<0.0001	42	84	0.07	13	0
But we’ll figure that out when we get there.	40	59	<0.0001	30	69	0.08	13	50
<b>Affirmation</b>	<b>Emp</b>	<b>Neut</b>	<b>p-val</b>	<b>M</b>	<b>F</b>	<b>p-val</b>	<b>B</b>	<b>W</b>
Yes that’s a good question!	58	64	<0.0001	44	78	0.8	50	0
I know this is not easy.	61	65	0.84	39	89	0.10	38	0
I understand same days every week could be hard to follow.	70	73	0.67	42	101	0.007	38	25
I know you will be feeling pushed in the beginning, but it will get easier.	70	79	0.44	49	100	0.33	38	0
<b>Social Dialogue</b>	<b>Emp</b>	<b>Neut</b>	<b>p-val</b>	<b>M</b>	<b>F</b>	<b>p-val</b>	<b>B</b>	<b>W</b>
I managed to increase my water intake through this approach.	65	67	0.001	39	93	0.04	13	0
If I don’t plan, I know I have the tendency to postpone things.	72	72	0.40	47	97	0.96	63	75
I love eating apples nowadays.	34	38	<0.0001	27	45	0.97	25	50
I go for a run three times a week.	43	39	0.26	32	50	0.22	13	0

**LEGEND:** Emp = empathic, Neut = Neutral, p-val = p-value, M = male, F = female, B = % cues helpful across all health behaviour, W = % cues helpful across total SRS measures.

We created tables that mapped each relational cue with each recommended behaviour and with each SRS element to see how often it was found to be helpful in order to identify any relationships between the cue's behaviour change or working alliance. For space, we only include in Table 3 the summary column that shows the percentage of the helpfulness of that cue for behaviour (B) and working alliance (W).

#### 4.4. Models Studying Relationship/Effect of Individual Factors on Change in Intention and Working Alliance

Individual factors such as gender, age and personality classification have further been analysed to determine if any group of users found any cues particularly helpful. We developed models using the method described in Section 3.3.5. Table 4 reports the models for each recommended health behaviour. Table 5 reports the F-score and top contributing features to analyse the relationship/effect of individual factors with a working alliance.

**Table 4.** Models with accuracy and top features for recommended health behaviours.

Training Dataset with Individual Relational Cues			
Model with Predictive Behaviour	Accuracy	F-Score	Top Contributing Factors
<i>Show Progress</i>			
Track your progress by automatic step counter	0.83	0.75	Top contributing relational cues are 50% affirmation and 50% social dialogue groups. Personality traits are less extroverted and highly agreeable, Ages 18–40 were dominant in changing intention, with most significant age bracket being 22–24.
Log your food choices in a food diary.	0.78	0.9	Top contributing relational cues are 50% from social dialogue group, 25% from affirmation and 25% from empowerment. Females prefer this change. Users who are highly introverted had preferred this change.
Tweak your daily activities to get closer to the goal	0.67	0.70	Top contributing relational cues are 25% from working alliance group, 50% affirmation, 50% from empowerment cues and 25% from social dialogues. Less extroverted and not open but highly agreeable users prefer this change.
<i>Goal Setting</i>			
Define a healthy activity goal for yourself.	0.70	0.78	Top contributing relational cues are 75% from working alliance, 50% from affirmation and 25% from empowerment cues. Personality, age or gender were not contributing factors.
Set an exercise goal	0.79	0.83	Top contributing relational cues are 50% from working alliance, 25% from affirmation, 25% from empowerment and 50% from social dialogues group. Users who are highly open and conscientious prefer this change.
Set a healthy eating goal	0.54	0.65	Top contributing relational cues are 75%, from affirmation group, 50% from empowerment and 25% from social dialogues group. Users who are less extroverted and not emotionally stable but are highly open prefer this change. Age contributes to the impact especially users who are in age range of 18–28.
Drink an additional glasses of water everyday	0.72	0.80	Top contributing relational cues are 25% from working alliance, 25% from affirmation and 25% from social dialogues group. Users who are less open but higher on agreeableness and conscientious prefer this change.
<i>Implementation intention</i>			
Link your health activities to specific moments in time	0.56	0.55	Top contributing relational cues are 25% from working alliance, 25% affirmation and 50% from empowerment group. Users who are less extroverted and not open but more agreeable prefer this change. Age has an impact with age range 18–40 more inclined to change.

**Table 5.** Models with accuracy and top features for working alliance.

Training Dataset with Individual Relational Cues			
SRS Components	Accuracy	F-Score	Top Features
I felt heard understood and respected	0.72	0.82	25% working alliance, 25% empowerment and 50% social dialogues. Extroversion, agreeable
We worked on and talked about what I wanted to work on and talk about	0.72	0.82	25% working alliance, and 25% affirmation, extroversion, conscientious, openness
Alex’s approach is a good fit for me	0.62	0.72	25% working alliance cues, 50% empowerment and 50% social dialogues, agreeable
Overall, today’s session was right for me	0.62	0.72	25% working alliance cues, 25% empowerment and 25% social dialogues, openness, agreeable.

## 5. Discussion

Relational cues have been used for building the dialogue of ECAs in previous health-related coaching solutions. However, analysis of which specific cues are found helpful and for whom has rarely been considered. Our study, in the first place, sought to determine whether the inclusion of relational cues resulted in our ECA being more usable and better able to build a working alliance or increase users’ intentions to follow healthy behaviours. We found no significant differences between the empathic (all relational cues) and neutral (no relational cues) versions of our ECA, indicating that relational cues do not always improve outcomes. Significantly, the neutral group report less system complexity, easier use and greater confidence, justifying our investigation to evaluate the value of including relational cues. Thus, the focus of this paper is on analysing specific relational cues in detail.

In answer to RQ1, we analysed whether there were differences between the empathic and neutral groups in terms of what relational cues they found to be helpful. Looking at the individual relational cues, 12 of them were liked by more than 60% of empathic and neutral users. None of these were empowering cues. Two of the significantly different cues were for building a working alliance using inclusive pronouns (“I hope together we can make progress towards becoming healthier”, “But we’ll figure that out when we get there”). They have an element of inclusivity and togetherness so as to build a better working alliance. Two other significant differences were for social cues (“I managed to increase my water intake through this approach” and “I love eating apples nowadays”), both of which are examples of self-disclosure in social dialogues, seeking to achieve deeper and more open conversations [40]. A single affirmation cue was significantly different (“Yes that’s a good question!”). However, four of these significant differences show that the higher scores were given by the neutral group. The interpretation of this may be that the statement itself is rated as helpful (i.e., the words sound as if the speaker is trying to be helpful), but when those words are actually uttered by an ECA, the user does not find them helpful. Other studies have found that users may consider the use of self-disclosure to be unethical [48] or be uncomfortable responding to questions that may imply the ECA is a human [49]. Our results suggest that cues involving self-disclosure, affirmation and inclusivity need to be designed with care and limited to those who find these acceptable from an ECA. For the remaining eleven cues, although not significantly different, four were liked by empathic Alex users more than neutral Alex users, but seven were liked more by neutral Alex users. The other two cues were social dialogue involving self-disclosure from the coach seeking to increase the quality of social interaction during the session (“If I don’t plan, I know I have the tendency to postpone things” and “I go for a run three times a week”).

The most liked cue (82% of users) by both groups is the empowerment cue, “If you set your own goal, chances are higher that you actually stick with them.” It has an element of motivation in it. Gibson [25] defined empowerment as a social process in health coaching aimed at promoting and enhancing a patient’s ability to meet their own needs. Empathy

through motivational and empowering statements [5] is one of the strategies to build a better-working alliance and establish the doctor–patient relationship. The cue that was liked the least was the self-disclosure cue “I love eating apples nowadays”, followed by “I go for a run three times a week”, which are both focused on the agent, not the user. The feedback from users suggests that most conversations need personalisation and topics to be highlighted based on the user’s interests. It could also be that the examples were not deemed feasible for the user. For example, maybe the user does not like or cannot eat apples due to a certain health issue [50].

The main objective of our study was to determine the relationship/effect of these relational cues on the intention to change certain health behaviours and build a working alliance with the health coach, taking us to RQ2. As there were few differences between the two groups, we combined the data for predictive analytics. The relational cues that were found helpful the most were the working alliance group of cues, with “I can encourage you to increase our set goals” and “Yes, that’s a good question” being the most helpful ones for 50% of the health behaviours of goal setting and showing progress groups. By using these cues, the most impacted behaviours were the first to define the healthy activity goal and the other to drink additional glasses of water. Goal setting and monitoring progress are linked to intrinsically motivated individuals [18] who further feel encouraged and appreciated by affirmative and encouraging dialogues. Research shows that such relational cues increase the likability and trust between the agent and the user [51,52] and can also increase the interaction time [53]. These belong to affirmation and encouragement cues in Bickmore’s work [7] and have been found beneficial in health-related coaching.

Breaking the working alliance into its components, it is not surprising that the most helpful cue for the task and goal components was from the working alliance cue group: “I can encourage you to increase your set goals”, showing that the user is relying upon the coach to help them through the journey and appreciates encouragement [10]. The cue that was found most helpful for bonding is the social dialogue cue: “If I don’t plan, I know I have the tendency to postpone things”. This is in line with the research on empathic dialogues that suggests disclosure from the coach helps users become more engaged and open in the conversation [5].

To answer RQ3, the study was designed to factor in gender, age and personality traits to determine whether relational cues helpfulness is affected by individual factors while measuring the change in intention or working alliance. This will establish traits that need to be built into future versions of health coaching solutions, along with customisation according to the chosen cues. In terms of gender, change in certain behaviours is more prominent in females for “log your food choices in a diary”, “set a healthy eating goal”, and “link your healthy activities to specific moments in time”. According to [54], females have an extreme response style, and hence, when analysing the top differentiating factors, females have a higher confidence score for change in intention. In terms of personality traits, these females are highly introverted, high on emotional stability, but low on openness. Introverts are more careful with decision-making [55]. In the case of working alliance, males have more impact on rating overall working alliance higher for Alex. These males are highly agreeable, extroverted and open in terms of their personality traits. Extroverts look for companionship and sharing of common ground [55], which makes them better candidates for building working alliances. While age did not appear to be in the top ten in most of the predictive models, intention to change for “Track your progress by automatic step counter” and “set a healthy eating goal” was greatest among young adults. Exercise and healthy eating is seen as common passion in young adults [56]; hence, modifying these behaviours is considered important in this age group. “Link your health activities to specific moments in time” has more impact on older adults who are managing their careers and building families, and thus, making a commitment to give time to themselves as well as scheduling it in their busy routine [57] is important for them.

## 6. Limitations, Future Work and Conclusions

This study lays a foundation for designing adaptive empathic health coaches. We aim to extend the work further by bringing in multiple coaches to provide coaching expertise that covers more than one domain area (e.g., diet, physiotherapy, diabetes, etc.) in the application. The aim is to expose the user to multiple viewpoints regarding their health and also to receive health support that is integrated with allied health providers.

The data collected and analysed are from a relatively small number of individuals who also represent a limited demographic. For example, if in the future we were to target elderly users, we would need to revisit and potentially modify some of our target behaviours by drawing on relevant health and psychology literature and with the involvement of relevant health professionals. The number of cues evaluated is small, and the dialogues were also of limited duration. Our findings are further limited to the factors captured in our study. Other factors, such as culture, are likely to influence behaviours [58]. The models uncovered connecting responses to our relational cues with demographic factors, working alliance, and behaviour change are thus not necessarily generalisable. Thus, further studies would be needed. We anticipate that digital health coaches will need to uncover models specific to their intended target users. What our results do reveal is that the impact of different relational cues will vary, and thus, tailoring is essential.

In the future, more tailoring of relational cues by adding personalisation could be achieved through the automatic generation of relational cues according to the preferences of the user to contribute towards building a context-aware bot. Natural language processing techniques for context categorisation and generation of a bag of words that is most suitable to the health domain can be explored. The third idea revolves around bringing more personality aspects into the dialogues involving showing empathy and adapting social dialogues based on individual factors of the user. For example, there can be a strong liking towards an assertive coach or vice versa. Hence, personality-based diversity can bring in more likability.

The main motivation behind this study was to analyse the impact of relational cues when it comes to health coaching delivered by an ECA. The use of the right motivational techniques, as well as the choice of words, have been shown to be vital in many domains where human interaction has been studied. This study has sought to understand how specific expressions of empathy and relational cues impact the human–ECA relationship and the value of this growing area of research for bringing about positive human health behaviour change.

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**Informed Consent Statement:** Not applicable.

**Data Availability Statement:** The data presented in this study is available on request from corresponding author. The data is not publicly available due to privacy regulations.

**Conflicts of Interest:** The authors declare no conflict of interest.



## Appendix A

There are a total of eight health behaviour changes in intention that is measured pre- and post-interaction with the coach. The impact of individual factors, personality of the user and exposure to the relational cues is given as input variables to the predictive model. Following is a list of input variables for one of the health behaviours impact predictions along with the target variable built on that specific health Behaviour.

1. ID: User Identifier
2. Gender: Male or Female
3. Age: Mentions the age of the student
4. HB2\_PRE: Likert scale rating for intention to change the health behaviour prior to interaction with the coach
5. SRSS\_1: Scale for the component of working alliance that talks about "bond" between the user and the coach
6. SRSS\_2: Scale for the component of working alliance that talks about "task" between the user and the coach.
7. SRSS\_3: Scale for the component of working alliance that talks about "goal" between the user and the coach.
8. SRSS\_4: Scale for the component of working alliance that talks about "overall session" between the user and the coach.
9. HB2\_POST: Likert scale rating for intention to change the health behaviour post interaction with the coach
10. RC1: Helpfulness rating for the relational cue 1 "I hope together we can make progress towards becoming healthier."
11. RC2: Helpfulness rating for the relational cue 2 "I can encourage you to increase our set goals."
12. RC3: Helpfulness rating for the relational cue 3 "As a team effort, if I show you how you're doing, you can see how close you are to reaching your health goals."
13. RC4: Helpfulness rating for the relational cue 4 "But we'll figure that out when we get there."
14. RC5: Helpfulness rating for the relational cue 5 "I know this is not easy."
15. RC6: Helpfulness rating for the relational cue 6 "I understand some days every week could be hard to follow."
16. RC7: Helpfulness rating for the relational cue 7 "I know you will be feeling pushed in the beginning, but it will get easier."
17. RC8: Helpfulness rating for the relational cue 8 "Yes that's a good question!"
18. RC9: Helpfulness rating for the relational cue 9 "If you agree to share this data, we can keep track of your steps."
19. RC10: Helpfulness rating for the relational cue 10 "If you decide to drink additional three glasses of water every day, I can tell you how you are managing to do so over time."
20. RC11: Helpfulness rating for the relational cue 11 "You can select different days of every week."
21. RC12: Helpfulness rating for the relational cue 12 "If you set your own goal, chances are higher that you actually stick with them."
22. RC13: Helpfulness rating for the relational cue 13 "I managed to increase my water intake through this approach."
23. RC14: Helpfulness rating for the relational cue 14 "If I don't plan, I know I have the tendency to postpone things."
24. RC15: Helpfulness rating for the relational cue 15 "I love eating apples nowadays."
25. RC16: Helpfulness rating for the relational cue 16 "I go for a run 3 times a week."
26. Extroversion: One of the dimensions of the TIPI personality scale that lets the user rate themselves on the specific trait.
27. Agreeableness: One of the dimensions of the TIPI personality scale that lets the user rate themselves on the specific trait.

28. Conscientiousness: One of the dimensions of the TIPI personality scale that lets the user rate themselves on the specific trait.
29. Emotional Stability: One of the dimensions of the TIPI personality scale that lets the user rate themselves on the specific trait.
30. Openness: One of the dimensions of the TIPI personality scale that lets the user rate themselves on the specific trait.
31. ChangeIntention: Target variable with values either 0 or 1. The value is 0, if the change in intention post interaction is less than Likert scale of 3 otherwise the value is 1.

The same variables are used in all models for intention to change prediction with these variables (HB2\_PRE, HB2\_POST) pointing to the Behaviour for which model is being built and target column (ChangeIntention) is also built according to the Behaviour under consideration.

## Appendix B

Models use classification and regression techniques to measure how much is the impact of input variables on the target variable. Following figures are snippets of python code for the model built for health Behaviour 2 (discussed in Appendix A).

1. From above variables, derived dataset is created resulting in one-hot encoded variables increasing the total input variables to 164.
2. After pre-processing train/test sets are built as shown in Figure A1.
3. Decision tree is built with a certain depth and entropy as shown in Figure A1
4. A pipeline of logistic regression classifiers is built so that best accuracy and F-score is extracted and validated as shown in Figure A2.

```
#First of all we will make train test split
from sklearn.model_selection import train_test_split
xtrain , xtest , ytrain , ytest = train_test_split(X,Y,test_size = 0.4, random_state=100)
print(xtrain.shape, ytrain.shape)
print(xtest.shape, ytest.shape)
```

```
(123, 126) (123,)
(83, 126) (83,)
```

```
# Train the Decision Tree Classifier with random state =100. No other parameter should be assigned.
from sklearn.tree import DecisionTreeClassifier

clf_dt = DecisionTreeClassifier(max_depth=8,criterion='entropy', random_state=100)
clf_dt.fit(xtrain,ytrain)
```

```
DecisionTreeClassifier(criterion='entropy', max_depth=8, random_state=100)
```

```
# Get the prediction from the model
dt_pred = clf_dt.predict(xtest)

from sklearn.metrics import accuracy_score , f1_score, r2_score
dt_accuracy = accuracy_score(ytest,dt_pred)

dt_f1score = f1_score(ytest,dt_pred)
print("accuracy : ",dt_accuracy)
print("F1 score for test :",dt_f1score)
```

```
accuracy : 0.7228915662650602
F1 score for test : 0.14814814814814817
```

**Figure A1.** Decision Tree classifier.

```

# Create first pipeline for base without reducing features.
from sklearn.linear_model import LogisticRegression
from sklearn.pipeline import Pipeline
from sklearn.ensemble import RandomForestClassifier
from sklearn.model_selection import GridSearchCV
pipe = Pipeline(['classifier', RandomForestClassifier()])
# pipe = Pipeline(['classifier', RandomForestClassifier()])

# Create param grid.

param_grid = [
    {'classifier': [LogisticRegression()],
     'classifier_penalty': ['l1', 'l2'],
     'classifier_C': np.logspace(-40, 40, 200),
     'classifier_solver': ['liblinear']}
    # {'classifier': [RandomForestClassifier()],
     # 'classifier_n_estimators': list(range(10,101,10)),
     # 'classifier_max_features': list(range(6,32,5))}
]

# Create grid search object

clf = GridSearchCV(pipe, param_grid = param_grid, cv = 5, verbose=True, n_jobs=4)

# Fit on data

best_clf = clf.fit(xtrain, ytrain)

```

Fitting 5 folds for each of 400 candidates, totalling 2000 fits

```

[Parallel(n_jobs=4)]: Using backend LokyBackend with 4 concurrent workers.
[Parallel(n_jobs=4)]: Done 200 tasks      | elapsed:    1.3s
[Parallel(n_jobs=4)]: Done 1400 tasks    | elapsed:    8.4s
[Parallel(n_jobs=4)]: Done 2000 out of 2000 | elapsed:   12.0s finished

```

```

# Get the prediction from the model
dt_pred = best_clf.predict(xtest)

from sklearn.metrics import accuracy_score , f1_score, r2_score
dt_accuracy = accuracy_score(ytest,dt_pred)

dt_f1score = f1_score(ytest,dt_pred)
print("accuracy in logistic regression: ",dt_accuracy)
print("F1 score for test in logistic regression",dt_f1score)

```

```

accuracy in logistic regression:  0.7831325301204819
F1 score for test in logistic regression 0.1

```

Figure A2. Logistic Regression classifier.

### Appendix C

Top contributing variables suggest the variable's weightage in impacting the intention to change for that particular behaviour. Figure A3 shows the variables in order of weights from highest to lowest.

	Feature Name	Importance
7	HB1_PRE_1	0.174366
8	HB1_PRE_2	0.166403
9	HB1_PRE_3	0.076497
4	SRSS_4	0.073413
19	RC2_3	0.049869
87	RC15_5	0.045324
82	RC14_5	0.043803
2	SRSS_2	0.039063
40	RC6_4	0.035284
44	RC7_3	0.035284
96	Extroversion_2.0	0.034991
3	SRSS_3	0.031090
21	RC2_5	0.030620
86	RC15_4	0.026523
105	Agreeableness_5	0.024976
0	age	0.023921
104	Agreeableness_4	0.023784
71	RC12_5	0.023116
102	Agreeableness_2	0.020948
123	Openness_3	0.020727

**Figure A3.** Input variables with their weightage in determining the target variable.

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