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Empirically understanding trust in medical technology

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ABSTRACT

Researchers across disciplines have developed measures of interpersonal trust, system trust, and trust in technology and sought to determine if measures of trust in technology should use the same trust factors as interpersonal trust measures. Studies have found evidence to support the notion that trust and distrust are considered opposites, negating the need for two separate measures to be developed and that participants rate concepts of generalized trust, interpersonal trust, system trust, and trust in technology similarly. It is not apparent if trust in medical technology is the same as trust in general technology; if the two constructs are different, existing trust in technology models may not be useful in discussions about medical technology. The studies involved in the development of a framework of trust in medical technology provide evidence to determine that trust in medical technology is empirically different from trust in technology. The methods described in the studies are based on research methods used to empirically define the constructs trust and comfort and were chosen to extend previous trust in technology models and to offer comparison and validation of findings and methods used in previous studies.

Relevance to industry: Understanding how users construct trust in medical technology provides insight to how medical technologies may be used, misused, disused or abused [Parasuraman, R., Riley, V., 1997. Humans and automation: use, misuse, disuse, abuse. Human Factors 39 (2), 230–253] by patients and health care providers and health system issues such as error, malpractice, adoption and satisfaction. The factors of trust in medical technology generated in these studies may be used for the development of trust in medical technology measurement tools. As will be shown, medical technology generalizes in many ways to other technology so the methods and results presented here have broader implications.

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1. Introduction

Technology is an essential component of a great variety of systems. This technology can be characterized by different levels of automation (Kleiner, 2006a). Generically, technology converts inputs to outputs using some transformation process. In information-intensive technology, data are converted to information for decision making. As suggested by Kleiner (2006b), medical technology follows the same characteristics as general technology in this regard. Focusing on the semi-automated levels, at Level 2, the operator is using the technology as a tool to search, scan or in some other way generate data so the human expert can make a diagnosis or decision. At Level 3, the technology is more sophisticated that a tool acts as a "partner' with the medical professional. Here the operator and technology have equivalent importance (though different roles perhaps) in generating useful outputs. At Level 4, the operator is more of a supervisory controller and the technology has taken over much more of the decision making and processing leading to a recommended course of action. Thus far, our description and taxonomy of technology is generic. What is unique to medical technology is that a human patient is the object being acted upon (converted from inputs to outputs) by the technology. In a sociotechnical systems sense then, the patient acts as both the product and the client and in such a system, the construct of trust has heightened importance.

Trust is as a feeling of certainty that a person or thing will not fail and is often based on inconclusive evidence. There are a variety of trust relationships such as, a human's trust with another human (interpersonal trust), a human's trust with a system or institution (social trust) and a human's trust with a technology or device (trust in automation). Social trust, which is influenced by factors such as the media and a generalized social confidence in the institution, is

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defined as trust in an institution (Pearson and Raeke, 2000). Low social trust is exhibited when certain ethnic groups have a low trust in health care as an institution because of historical oppression and deception to their cultural group (Doescher et al., 2000). If an individual patient does not trust their doctor because the doctor has been assessed as untrustworthy over time, this is interpersonal trust. To trust a technology or automation is to believe that a tool, machine or equipment will not fail (Sheridan, 2002).

The concept of human trust has been explored in complex automated systems (Dzindolet et al., 2003; Madhavan et al., 2006; Lee and See, 2004) and online systems (Corritore et al., 2003; Daignault et al., 2002; Friedman et al., 2000). Several key findings from this scholarship include an understanding of the relationship of trust in automation in terms of reliance, compliance and rejection. Research conducted by Lee and Moray (1992,1994) found that operators' belief in their own abilities was related to their respective trust in the automation. Parasuraman and Riley (1997) identified that trust in automated systems can lead to appropriate use, disuse, misuse or abuse of the automation.

Trust scholarship in health care work systems has focused on interpersonal trust between patients and physicians (Franks et al., 2005; Hall et al., 2002; Pearson and Raeke, 2000; Tarn et al., 2005; Thom et al., 1999) and patient's trust in health systems (Balkrishnan et al., 2004; Zheng et al., 2002; Hall et al., 2002). Patient's trust has been linked to important organizational and economic factors such as decreases in the possibility of a patient leaving a care providers practice and withdrawing from health plan (Pearson and Raeke, 2000). Some interpersonal trust researchers believe that technology replaces human elements in medical practice and may reduce patient's trust in physicians (Boehm, 2003). In essence, the level of automation is increasing, leaving a lesser "perceived" role of providers by patients.

Medical technology has been defined similarly, across groups such as designers, educators, researchers, practitioners and government health and human service organizations, as tools used on the body for health purposes (OTA, 1992; DeMiranda et al., 2005; AAAS, 1990). As previously stated, like in other applications, the range of automation and uses of medical technology are extensive. Operators can be technicians, nurses, physicians and patients themselves in the case of home health care. Understanding trust in medical technology in relation to other aspects of the health care systems is important for the assessment and design of systems and can only be examined with an effective measurement tool. Researchers have asked if understandings from trust research in one domain are transferable to other domains such as health care (Moffa and Stokes, 1997). Others have predicted increases in the use automation and technology in health systems (Felder, 2003). However, it is not clear in the literature if trust in different systems is the same as in other systems. Understanding the limitations/specificity of trust across context will provide guidance to the interchangeability of trust measurement.

Researchers have explored trust versus distrust in the context of interpersonal trust, organizational trust (Bao et al., 2005; Kramer, 1999), trust in technologies (Dzindolet et al., 2003; Grabner-Krauter and Kaluscha, 2003; Charki and Josserand, 2008; Guha et al., 2004; McKnight et al., 2004) as well as intersection between the constructs (Madhavan and Weigman, 2007). Jian et al.'s (2000) study of trust in technology implies that participants rate human–human trust in less extreme ways than when rating human–machine trust, but that trust and distrust are opposites of the same construct in human–human and human–machine contexts. Other researchers have described trust and distrust in terms of conditions that must be met, such as users are distrustful of technologies until they have been proven successful (Sheridan, 2002; Parasuraman and Riley, 1997). Researchers have found a negative relationship between trustworthiness and use (Benamati et al., 2007; Muir and Moray, 1996). Muir and Moray (1996) found through experimentation that operators' distrust in a function reduced trust in other functions of the same element; distrust did not generalize to similar components in the same system or in other systems. They also found that participants used automation they trusted and chose to perform tasks manually when they distrusted the automation. Other studies in trust in online systems have found that trust and distrust are distinct constructs (Benamati et al., 2007). E-commerce researchers have found that measures trust and distrust tend to predict different variables; specifically a relationship between distrust and technology use related factors such as information sharing and purchase (McKnight et al., 2004; McKnight and Choudhury, 2006).

The purpose of this research was to explore human conceptions of trust in technology and trust in medical technology, to develop an understanding of the shared features and differences between the constructs. This work will provide a guideline for how existing trust in technology discourse will fit in the design and evaluation of health care work systems.

2. Study one: generating factors of trust in medical technology

Study one obtained a collection of terms associated with trust and distrust of technology and medical technology. The goal of this study was to provide evidence towards understanding trust in medical technology as the same or different from trust in technology.

2.1. Method

2.1.1. Participants

Native English speaking Participants with academic and professional backgrounds in English and linguistics were recruited through a Psychology research website and a linguistics listserv. Forty-eight participants volunteered to participate and 21 dropped out before completing the study. Participants ages ranged from 18 to 44 with $M = 26$ SD = 7.9. Seventy-four percent self-identified as White/Caucasian, 4 percent as African American/Black, 4 percent as Hispanic, and 11 percent as Asian/Pacific Islander. Education in years was reported from 12 to 21 with $M = 15$ SD = 2.44

2.1.2. Procedure

Participants first provided an open-ended definition of their understanding of trust and distrust in technology and another of medical technology. Second, participants were given a list of 160 trust-related words obtained from Jian et al.'s (1998) study to rate on a three-point Likert-type scale ranging from "positively related to trust in medical technology" to "not at all related to trust in medical technology" to "negatively related to trust in medical technology." The procedure was repeated with the same list of words for trust in technology.

2.1.3. Analysis

Participant open-ended definitions were coded under the themes of trust in medical technology, distrust in medical technology, trust in technology and distrust in medical technology. Units of analysis were at the word level. All 27 participant responses were coded and included in the analysis.

Positively and negatively related words were included in the study two word pool. Words rated as "not at all related" to trust by

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25% or more of the group were dropped from the word pool. Words that received conflicting ratings were also dropped (i.e. rated both positively and negatively). New words defined in the open-ended definitions of trust/distrust in technology and medical technologies were included in study two.

2.2. Results

Thirty-nine additional trust and distrust related words were included in the final set of factors for the next study. Conceptually different definitions were provided for trust and distrust related to medical technology as opposed to a non-specified type of technology.

For Trust in Technology, Likert responses out of 160 words, 40 passed Criterion 1 (not at all related by 25% or more) and 91 passed Criterion 2 (conflicting ratings). For Trust in Medical Technology, out of 160 words, 56 passed Criterion 1(not at all related by 25% or more) and 89 passed Criterion 2 (conflicting ratings). Twenty-seven words met both criteria for trust in technology and 37 words met both criteria for trust in medical technology (see Table 1).

Table 1
Words to be included in the study.

	Trust in technology	Trust in medical technology
1		Absolute
2		Anger
3	Assurance	Assurance
4		Attack
5	Can_be_relied_upon	Can_be_relied_upon
6	Certain	Certain
7	Certainty	Certainty
8		Competence
9	Confidence	Confidence
10	Constancy	Constancy
11	Cooperation	Cooperation
12	Count_on	Count_on
13		Cruel
14	Deception	Deception
15		Definite
16	Distrust	Distrust
17	Doubt	Doubt
18	Error	
19		Entrust
20	Failure	Failure
21		Falsity
22	Harm	Harm
23	Hesitation	
24	Honesty	Honesty
25	Integrity	Integrity
26	Misleading	Misleading
27	Mistake	Mistake
28	Mistrust	Mistrust
29		Overtrust
30	Positive	Positive
31	Reliability	Reliability
32	Reliable	Reliable
33	Secure	Secure
34	Security	Security
35		Security_in_caring
36		Trustworthy
37		Understandability
38	Usefulness	Usefulness
39	Wrong	Wrong

Shading indicates a word that appears in one set and not the other.

2.3. Discussion

It was expected that participants would provide similar definitions of trust in technology as with trust in medical technology, however the results show that participants provided mostly similar responses but not similar enough to indicate that participants' view trust in technology the same as trust in medical technology. In the rating portion of the study, more words passed both criteria for trust in medical technology than trust in technology, which may indicate that trust in medical technology encompasses more dimensions than trust in technology. The words that differentiate trust in medical technology from trust in technology according to the results are; Absolute, Anger, Competence, Attack, Cruel, Definite, Entrust, Falsity, Overtrust, Understand ability, Trustworthy, Security_in_caring. The words that differentiate Trust in Technology from Trust in Medical Technology are: Error and Hesitation.

It was also expected that new terms would be added to the list of words that differentiate trust in medical technology from trust in an unspecified type of technology. Themes that arose in the analysis of trust in medical technology open-ended responses included notions of trust in physician, ideas about technological advancement or innovation, research, and trust in medical systems. The theme of technological advancement was included in analysis of trust in technology, but was represented more as a desire to try or own advanced technology (i.e. "Trusting technology and its advancements allows you to move ahead of the old ways," P1) as opposed to a suspicion of new advances (i.e. "doubting new advances in medicine," P17).

In open-ended responses, participants described trust in technology in three different categories:

1. Actions that a person performs when they trust a technology. Examples include: using a technology, consenting to use, purchasing, trusting it with important information or safety.
2. Feelings about the technology. Examples include: having faith, believing in the technology, and feeling comfortable.
3. Actions that the technology performs to lead to trust or distrust. Examples include: being accurate, being reliable, being understandable, being easy to use, and matching assumptions.

Thinking of trust in technology along these categories may provide insight into various ways of measuring trust (i.e. based on actions a trusting person performs). This information may also distinguish between trust as a belief system and trust as a product of a technology's performance.

2.4. Limitations

Mortality was a threat to validity as many participants dropped out of the study before completing which could be an indication of the study being too long and/or tedious. These drop-outs are likely related to the study being conducted online.

3. Study two: comparing trust across contexts

The goal of the second study was to identify a smaller set of terms strongly related to trust and distrust in medical technology. The results of this study provided evidence to answer the research questions:

3.1. Method

3.1.1. Participants

104 responses were evaluated after many respondents were dropped due to missing data. Participants ages ranged from 18 to 40 with $M = 19.9$ $SD = 2.38$. Eighty one percent of participants self-identified as White/Caucasian, 9 percent as Asian/Pacific Islander, 6 percent as African American/Black, 1 percent Hispanic, 1 percent multi ethnic, and 2 percent declined to respond. Education in years

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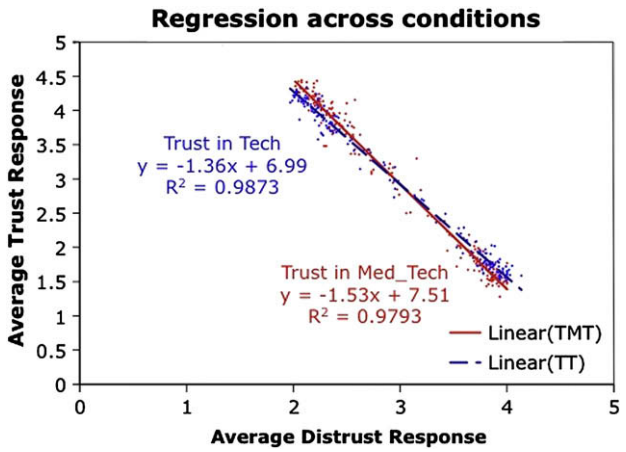

Fig. 1. Regression across conditions trust in technology and trust in medical technology.

ranged from 12 to 15 with $M = 13.7$ SD $= 1.19$. Participants were all native English speakers.

3.1.2. Apparatus

An online questionnaire was developed with each of the words generated from study one. Each of the four questionnaires contained a five point Likert-type scale with levels ranging from positively to negatively related to trust or distrust.

3.1.3. Procedure

Participants were asked to complete all four questionnaires. In each questionnaire, participants were asked to rate words, from the list derived in study 1, as ranging from positively to negatively related to trust in medical technology or trust in technology.

3.2. Results

3.2.1. Correlation

Average ratings for each word were calculated for all four conditions: trust in medical technology; distrust in medical technology; trust in technology; and distrust in technology. A multivariate Pearson correlation analysis for each word for rating of trust versus distrust was conducted for trust in medical technology and trust in technology P. Ratings of trust were highly, negatively correlated with ratings of distrust ($r = -0.99$ $r = -0.99$ respectively) (Table 3).

Words with high positive ratings for trust also had high, negative ratings for distrust. This indicated that concepts for trust and distrust are opposites rather than containing different factors. Pairwise Pearson correlations were also calculated. The Pearson correlation between all variables pair was 0.99 $p < 0.0001$, with a count of 188 used for the computation.

3.2.2. Regression

Results were analyzed using bivariate correlation and simple linear regression (Table 3). Distrust score were regressed on the trust scores separately for the conditions technology and medical technology. The variation in distrust in medical technology

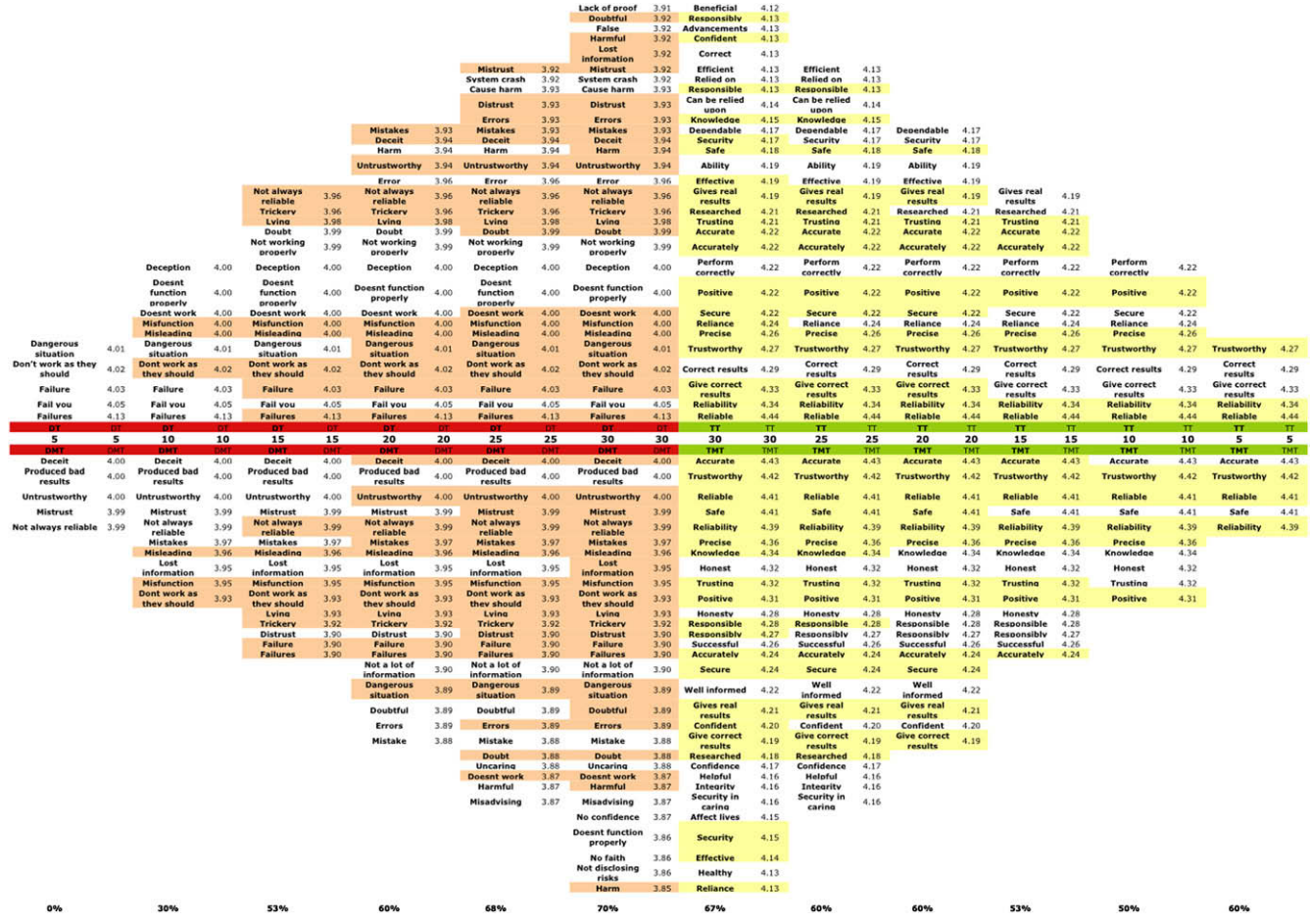

Fig. 2. Uniion sets with means and factors for trust and distrust across conditions.

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accounted for 98% of the variance in trust in medical technology ($R^2 = 0.979$) and 99% for trust in technology ($R^2 = 0.987$), which suggests a good fit with the data. All conditions were significant at $p < 0.0001$. Regression lines were plotted for Trust in Technology and Trust in Medical Technology (See Fig. 1).

Results were analyzed using a paired-samples *t*-test. This analysis revealed a significant difference between mean levels of trust in technology and trust in medical technology, $t(187) = 3.903$; $p < 0.0001$. The sample means show that mean trust scores appear significantly higher in the trust in technology condition (mean = 2.94) than in the trust in medical technology condition (mean = 2.90), the observed difference between the scores was 0.0435, and the 95% confidence interval for the difference extended from 0.0215 to 0.0655. The effect size was computed as $d = 0.2847$. This represents a small effect (Cohen, 1992).

3.2.3. Union sets

Union sets were created from 5 to 30 words, to assess the overlap between the highest responses on variables trust and distrust, for the conditions technology and medical technology. Ranging from 5 to 30 allows for a clear representation of the points at which the sets merge or deviate based on the representativeness of the group. For example, of the five words that received the highest ratings of words related to trust for the variables technology and medical technology, three of the words trustworthy, reliability, and reliable are found in both trust in medical technology and trust in technology, to produce a 60% union match. The lowest percent of overlap between words associated with technology and medical technology was 0% at the distrust union set with five words. The highest percent of overlap was 70% at the distrust union set with 30 words. Matched words and words included in the sets can be found in Fig. 2. In the figure highlighted word indicates words found in the union set for both trust in technology (TT) and medical technology (TMT). Fig. 3 also shows which words were most strongly related to trust in generic technology and trust in medical technology.

3.2.4. Principal components analysis

Principal components analysis was used to analyze responses to the 188 item questionnaire. The principal axis method was used to extract the components, and this was followed by a varimax (orthogonal) rotation. Using Kaiser's rule, components with eigenvalues greater than 1 were retained (Kaiser, 1970). 42 components from the trust in medical technology condition were retained for rotation and 37 from trust in technology. Combined, the components account for 87.2% and 87.5% of the variance (see Table 2).

Questionnaire items and the corresponding factor loadings are presented in Table 3. In interpreting the rotated factor pattern, an item was said to load on a given component if the factor loading was 0.40 or greater for that component and less than 0.40 for the other. The first three factors were examined after rotation. For the first factor, 79 factors were produced for trust in technology and 76 for trust in medical technology. Ninety five percent of the factors overlapped between both conditions. For the second factor, 12 factors were produced for trust in technology and 33 for trust in medical technology. Zero percent of the factors overlapped between both conditions. For the third factor, 11 factors were produced for trust in technology and five for trust in medical technology. Zero percent of the factors overlapped between both conditions.

3.3. Discussion

The correlation analysis provided evidence to support the hypothesis that trust and distrust are theoretical opposites across

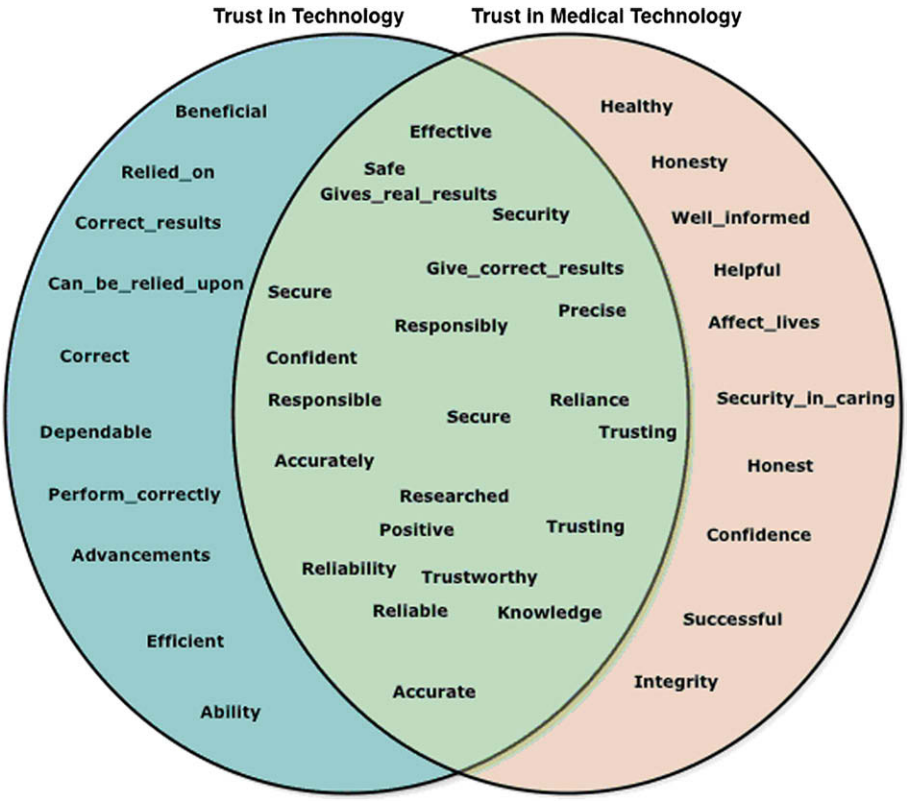

Fig. 3. Overlap of factors of trust in technology and trust in medical technology.

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Table 2
Eigenvalues and percent variance for TMT and TT.

	TMT			TT		
	Eigenvalue	Percent	Cum percent	Eigenvalue	Percent	Cum percent
1	51.21	27.24	27.24	73.90	39.31	39.31
2	18.40	9.79	37.03	13.93	7.41	46.72
3	6.83	3.63	40.66	5.71	3.04	49.75
4	5.34	2.84	43.50	4.90	2.61	52.36
5	4.78	2.54	46.05	4.36	2.32	54.68
6	4.47	2.38	48.42	4.17	2.22	56.90
7	4.00	2.13	50.55	3.50	1.86	58.76
8	3.73	1.98	52.53	3.26	1.73	60.49
9	3.50	1.86	54.39	3.08	1.64	62.12
10	3.46	1.84	56.23	2.84	1.51	63.63
11	3.24	1.72	57.96	2.77	1.48	65.11
12	3.04	1.62	59.57	2.72	1.44	66.55
13	2.96	1.57	61.15	2.57	1.36	67.92
14	2.86	1.52	62.67	2.35	1.25	69.17
15	2.69	1.43	64.10	2.32	1.23	70.41
16	2.63	1.40	65.50	2.19	1.16	71.57
17	2.45	1.30	66.80	2.10	1.12	72.69
18	2.37	1.26	68.06	1.93	1.03	73.71
19	2.24	1.19	69.25	1.90	1.01	74.72

the conditions trust in technology and trust in medical technology. This means that distrust is not a separate construct from trust, which matches findings in previous studies (Jian et al., 1998). This evidence allows for simplified considerations of trust in technology and medical technology recommendations as well as in the creation of measures of trust. For example, if the factor "easy to use" was considered a factor towards the trustworthiness of an interface or device. In order to make a technology more trustworthy a designer need only make it easier to use, in contrast making the technology less easy to use contributes to distrust in a device. The results of the correlation analysis also showed that trust across the conditions technology and medical technology behave in a similar bipolar way.

The regression analysis and subsequent paired *t*-test provided evidence that trust in medical technology and technology are perceived differently by research participants. This finding means that previous understandings of trust in technology may not be transferable to conversations about medical technology and medical systems.

Union sets analysis provided more evidence that trust in technology and medical technology are perceived differently between research participants. Of the top five words rated most related to trust in technology and medical technology, only 60% were the same across conditions (see Fig. 3), which shows that participants are thinking of the two, constructs differently. Principal component analysis provided additional evidence that trust in technology and trust in medical technology are different constructs with similar attributes.

4. Conclusion

This research provided evidence of how people define trust in medical technology as a construct. The first study found that participants believed that 73% of the words for trust in technology and trust in medical technology were the same. Study two found trust and distrust to be opposite anchors of the same dimension in both trust in medical technology and trust in technology. These findings are similar to Jian et al.'s (1998) findings in which trust and distrust between people and technology were found to be theoretical opposites. Study two also found that participants' perceive trust between technology and trust in medical technology differently. This may be because of the unique role the human patient plays within the system.

Table 3
Correlations of trust by distrust.

Variable	by Variable	Correlation	Count	Signif prob
medtech_distrust	medtech_trust	−0.99	188	<0.0001
tech_trust	medtech_trust	0.99	188	<0.0001
tech_trust	medtech_distrust	−0.99	188	<0.0001
tech_distrust	medtech_trust	−0.99	188	<0.0001
tech_distrust	medtech_distrust	0.99	188	<0.0001
tech_distrust	tech_trust	−0.99	188	<0.0001

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