Improving Understanding of Test Results by Substituting (Not Adding) Goal Ranges: Experimental Study

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Abstract

Background: Most displays of laboratory test results include a standard reference range. For some patients (e.g. those with chronic conditions), however, achieving a result within the standard range may be unachievable, inappropriate, or even harmful.

Objective: To test the impact of including clinically-appropriate goal ranges outside the standard range in visual displays of laboratory test results.

Materials and Methods: Participants (N=6776) from a demographically diverse online panel viewed hypothetical hemoglobin A1c test results (either A1c=6.2% or =8.2%) as part of a type 2 diabetes management scenario. Test result visual displays included either (1) standard range (4.5%-5.7%) only, (2) a goal range (6.5%-7.5%) added to standard range or (3) goal range only in one of three display formats: (a) table, (b) a simple, two-colored number line (simple line), or (c) a number line with diagnostic categories indicated via colored blocks (block line). Primary outcome measures were comprehension of and negative reactions to test results.

Results: While goal range information did not influence understanding of A1c=8.2% results, goal range only displays produced higher levels of comprehension and decreased negative reactions to A1c=6.2% test results compared to the no goal range and goal range added conditions. Goal range information was less helpful in the block line condition versus other formats.

Conclusions: Replacing the standard range with a clinically-appropriate goal range could help patients better understand how their test results relate to their personal targets.

Introduction

In an effort to facilitate greater patient involvement in the management of their health, hospitals and health care systems have increasingly provided patients with access to their electronic health record (EHR) [1]. However, simply providing health information, such as laboratory test results, is often insufficient in enabling patients to understand, much less utilize, this information. Test results are commonly presented in a table format, a format that leaves a sizeable minority of people having difficulty with the seemingly simple task of identifying whether their test result is in the standard range or not [2]. Furthermore, even when people can correctly identify the location of their test result in reference to the standard range, they tend to view the risk associated with their test value in a dichotomous fashion—with results in the standard range being viewed as "good" and results outside of the standard range as "bad"—without sensitivity to the fact that risk usually changes in a linear or exponential fashion [2].

Individuals who manage chronic conditions face an additional barrier to understanding and effectively using their test results: inappropriate reference ranges. The standard range commonly presented as part of test result communications represents the distribution of values commonly observed in a healthy population [3–5]. In some chronic disease situations, however, the practical target range that the patient and clinician are trying to reach may be substantially different than the standard range. For example, the standard range for hemoglobin A1c is generally something like 4.5-5.7 %, but a common recommendation for patients with type 2 diabetes is to aim to have their A1c values below 7%. Furthermore, there is evidence that aggressively managing type 2 diabetes (A1c goal: <6.0%) in older individuals results in increased mortality compared to standard therapy (A1c goal: 7.0%-7.9%) [6–9], suggesting that at least some patients (e.g., those experiencing frequent hypoglycemia) may need to be told that their hemoglobin A1c is lower

than advisable. Even in situations where the patient may not be physically harmed by trying to reach the standard range, if the standard range is not realistically achievable, patients may feel justifiably frustrated and discouraged. This could lead to decreased motivation for self-management or the pursuit of alternate therapies in an effort to achieve the unachievable. In an attempt to avoid these potential harms, health care providers frequently discuss goal ranges with their patients that may be more realistic for a person with their condition. Goal ranges may also change with new evidence or changing life circumstances, so it may be important to have ways to communicate these goal ranges in the patient portal.

In addition to the use of clinically-appropriate goal ranges, use of visual displays could help to increase patient sensitivity to variations among out-of-range results. In a previous study from our research group we tested the impact of presenting laboratory test results via three number line formats versus a standard table format on participants' sense of urgency and desire to contact their health provider [10]. Compared to participants in the table condition, participants in the three number line displays had reduced perceived urgency and desire to contact their health provider for test result values outside of, but near, the standard range. Furthermore, the use of visual displays did not affect participants' perceived urgency and desire to contact their health provider about more extreme test values.

These issues raise the question of how can test results be communicated to patients in ways that help them to better understand how their result compares to the target range most relevant to their self-management and treatment decision making? To the best of our knowledge, there has been no research that examines whether and how individual- or disease-specific goal range and/or standard range information should be incorporated into the return of laboratory test results

for patients such as these. Inclusion or exclusion of different combinations of these reference standards might improve comprehension of the test value and reduce unnecessary negative reactions, such as discouragement or urgency to contact their health care provider when urgency is not needed.

We conducted an online experiment in which respondents imagined receiving hemoglobin A1c test results through an EHR patient portal as part of the ongoing management of their type 2 diabetes. This study was designed to answer 4 key questions:

1. Does the inclusion of goal range information improve comprehension of the test results?
2. Does the inclusion of goal range information reduce unnecessary negative reactions to test results that are outside of the standard range, but near their goal range?
3. Is it better to include the goal range information in addition to, or in place of, the standard range?
4. Does the display format (e.g., table v. visual number line) change any impact of including goal range information in the test result display?

Utilizing the principle “less is more”, which has been shown to apply in health communication [11–14], we hypothesized that the goal information would have the largest improvements in comprehension and reducing unnecessary negative reactions when the goal range was the only reference category (i.e., conditions where the standard range and any other risk categories are absent). We also hypothesized that the impact of goal information would be most effective for values nearer to, but still outside of, the standard range, since higher test values would be comparatively easier to interpret without additional information.

Methods

Setting

Data were collected through Qualtrics® survey software from a nationwide sample of U.S. adults through Survey Sampling International (SSI). Participants were recruited over a 2-month period from August 2015-October 2015.

Sample

Participant eligibility was determined by SSI through the use of a probability-weighted random process based on sample requirements. We established quotas on respondent age (33% aged 21-39; 33% aged 40-49; 33% aged 60 or older), gender (50% female), and race/ethnicity (14% African American; 14% Hispanic; 4% Asian American) to approximate the distribution of these characteristics in the U.S. population, but oversampled individuals with diabetes, to ensure that we did not have an overly healthy sample and to evaluate whether experience managing diabetes moderated the impact of the goal presentation format. SSI participants were routed to the survey via the sampling algorithm until all quotas were achieved.

Design and Procedure

Participants were asked to imagine that they had recently visited their doctor's office to discuss the management of their type 2 diabetes, during which their doctor highlighted that people with type 2 diabetes should try to have hemoglobin A1c values within a target or goal range of 6.5%-7.5%. Participants were then asked to imagine that in the intervening 3 months, they did their best to follow their doctor's recommendations (e.g., exercising regularly; eating healthy). Then, 3 months prior to their next appointment, the patient had some blood tests completed and viewed the results of these tests a day later via an online EHR portal.

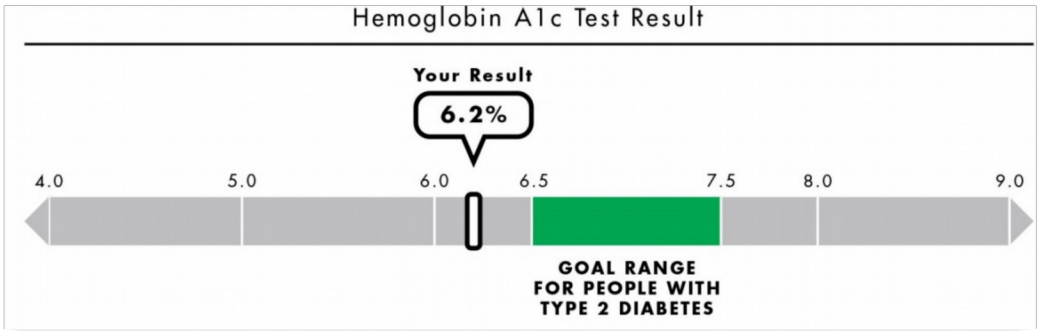
We tested 3 between-subjects factors (varied independently) to examine the impact of including goal range information across different presentation formats on patient reactions to their test results. (For examples of different levels of each factor, see Figure 1). The first factor was *goal presentation*. Approximately one-third of participants were randomly presented with a test result display with no goal range (*standard range only* condition), although the goal range information was described in the scenario text. The remaining participants received visual displays with the goal range included, either in the addition to the standard range (*goal range*

Figure 1. Examples of different goal presentation and display formats. Example labels indicate the display format, goal presentation, and A1c test value conditions being represented.

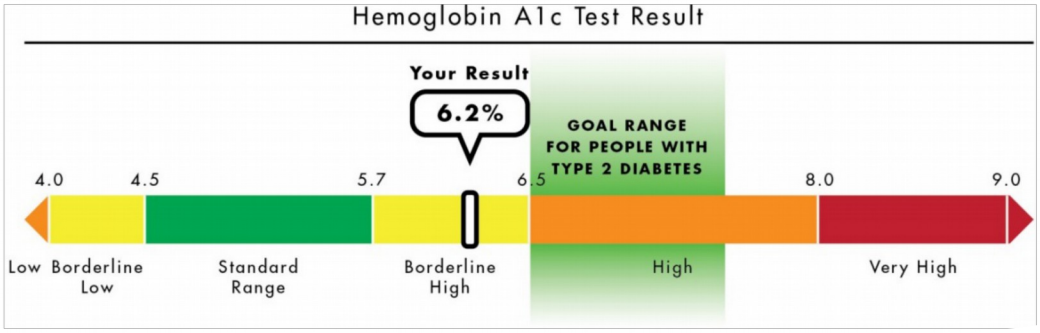
Table, goal range added, 8.2% A1c test value

Test	Your Result	Standard Range	Goal Range For People With Type 2 Diabetes	Units
Hemoglobin A1c	8.2	4.5-5.7	6.5-7.5	%

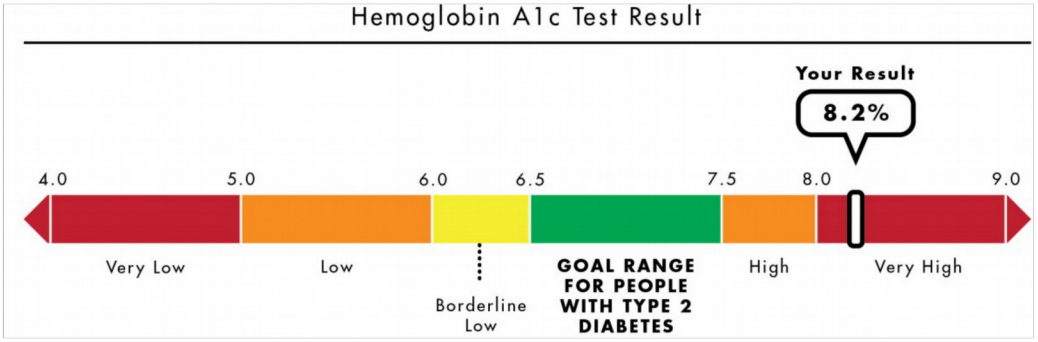
Simple line, goal range only, 6.2% A1c test value



Block line, goal range added, 6.2% A1c test value



Block line, goal range only, 8.2% A1c test value



added condition) or with the goal range presented instead of the standard range (*goal range only* condition). The goal range was chosen in consultation with clinicians on our research team who care for patients with type 2 diabetes to represent a realistic and clinically-appropriate target range for most individuals who have type 2 diabetes.

The second factor was *A1c test value*. Participants were randomly presented with an A1c test value of 6.2%, which fell between the standard range and the goal range, or 8.2%, which was higher than both the standard and goal ranges.

The third factor was *display format***.** The A1c test result was randomly presented via one of three formats. The *table* format presented information via text in a table, the format typically used in EHRs. The *simple line* format was a grey number line, except for a green range labeled "standard range". The *block line* format was a number line divided into differently colored diagnostic ranges. The cutoffs for the diagnostic categories were determined in consultation with clinician team members an differed for the "goal range only" condition compared to the "standard range only" and "goal range added" conditions to reflect differences in hypoglycemia risk for individuals with type 2 diabetes compared to the general population. We reviewed our designs in color vision difference simulators to ensure that the different colors were distinguishable for people with color vision differences. For the "block line" plus "goal range only" combinations, the "Borderline Low" label was represented differently (dropped down, with dotted line connection) as a result of the label being longer in length than the range on the number line. For additional information on the display formats, please refer to our previous research utilizing these designs [10].

Measures

Comprehension

We included two measures to assess how well participants understood their test result in relation to their goal range. For the *relative location* measure, we asked "Where was your test result compared to your goal range?" with "higher than the goal range", "within the goal range", "below the goal range", and "I don't know" as response options. For the *future location* measure, we asked "At your next test, what do you think your next test result should be, as compared to this test result?" with a 9-point Likert scale response option with "A lot lower" and "A lot higher" as the anchor labels and "About the same" as the mid-point label. "I don't know" was also included as an additional response option.

Reactions to Test Result

We included two measures to assess participant reactions to their test result: one measuring how discouraged they would be by their test result and one assessing if and when they would contact their doctor about their test result. For the *discouraged* measure, we asked "How discouraged or encouraged do you feel about this test result?" with a 6-point Likert scale response option with "Very discouraged" and "Very encouraged" as the anchor labels, with an additional "I don't know" response option. For the *urgency* measure, we asked "How soon do you need to speak to your doctor regarding these results?" with "Immediately", "Within a few weeks", "At your next appointment in 3 months" and "I don't need to speak to my doctor about these results" as response options.

Demographics

We asked participants their age, gender, race and ethnicity, education, whether they have diabetes, and if so, what type.

Data management

All data were collected anonymously in that the researchers had no way to learn the identity of the participants. A unique identification number provided by SSI was contained in the redirected URL which identified participants and prevented them from completing the study multiple times. This study was deemed exempt by the University of Michigan Health Sciences and Behavioral Sciences Institutional Review Board.

Data analysis

Recoding of measures

Responses to the *relative location* measure were recoded as '1' to indicate a correct response if they responded "below the goal range" in the 6.2% A1c test result condition or "higher than the goal range" in the 8.2% A1c test result condition. All other responses were recoded as '0' to indicate a failure to know where their test value was in relation the goal range. To assess whether participants had the gist of where their next test value should be, *future location* responses were recoded as '1' if they were above the midpoint of the scale in the 6.2% A1c test result condition and below the midpoint in the 8.2% condition. All other responses were recoded as '0'. The results are substantially the same, if not stronger (i.e., larger effect sizes), if "about the same" is coded as '1'. The one exception is that having diabetes is associated with increased comprehension of the future location for the goal presentation and display format logistic regression analysis. Responses to the *discouraged* and *urgency* measures were reverse coded, such that higher scores indicated greater discouragement and urgency, respectively. We recoded gender (0=male, 1=female), race (0=White, 1=non-White) and diabetes status (0=No diabetes; 1=diabetes).

Effects of goal presentation

We report percentages for the relative and future location measures and descriptive measures for the discouraged and urgency measures across the different factors. We used chi-square analyses to test for differences in percentages and independent sample t-tests and one-way ANOVAs with post-hoc comparisons using Bonferroni corrections for multiple comparisons to compare means. We also report the logistic regression results for the relative and future location measures and ordered logistic regression results for the discouraged and urgency measures, with age, gender, race, education and diabetes as covariates to test whether including relevant covariates substantially change the results from the chi-square, t-test, and ANOVA analyses. All analyses were performed using Stata 14 and all tests of significance were 2-sided and used α=.05.

Results

Sample description

Out of the 8161 participants who initiated the study, 6781 (83.1%) completed it. In addition, 14 responses were dropped due to a reported age <18 years old and 1 response was dropped due to a reported age of 586. Table 1 reports sample demographic characteristics among the remaining 6766 participants.

Impact of goal presentation on interpretation of tables

In univariate analyses of participants receiving A1c=8.2% in table form, neither goal presentation or display factors significantly affected any of the outcomes (all *P*s>.07; see Figure 2).

Among participants who received tabular displays of A1c=6.2% results (which fell between the standard and goal ranges), however, goal presentation format had a significant impact on comprehension. As shown in Figure 2, receiving explicit goal information (in either form)

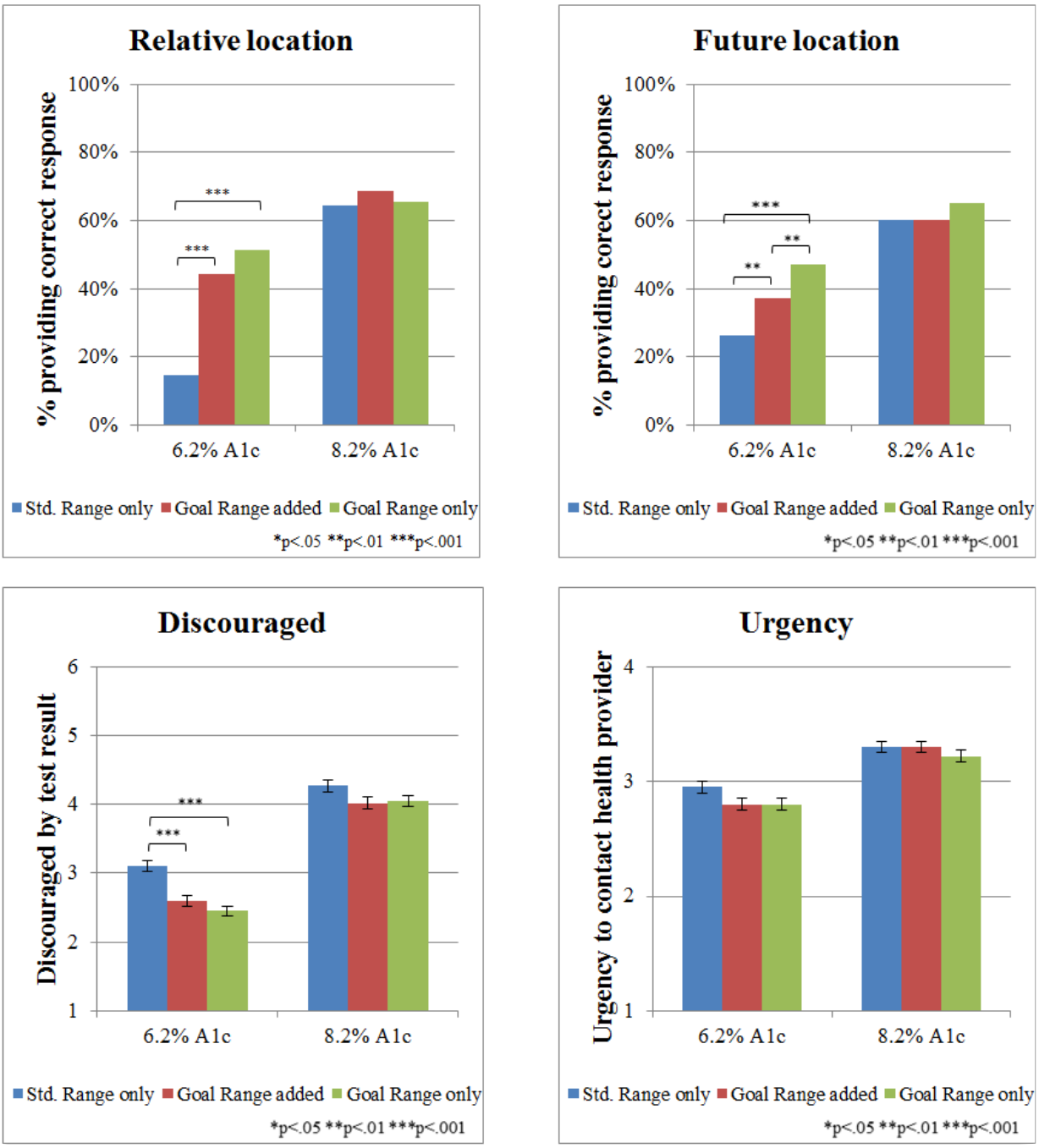
Table 1. Sample characteristics (n = 6766).

Characteristic	Category	Frequency (%)	Mean (SD)
Age			49.1 (15.8)
Gender			
	Male	3299 (48.9%)	
	Female	3435 (50.9%)	
	Transgender/Other	15 (0.02%)	
Ethnicity			
	Hispanic (any race)	892 (13.3%)	
Race[a]			
	White	5294 (78.2%)	
	African-American	1002 (14.8%)	
	All other	654 (9.7%)	
Education			
	<High school	135 (2.6%)	
	High school only	1065 (15.8%)	
	Some college/trade	2458 (36.4%)	
	Bachelor's degree	2005 (29.7%)	
	>Bachelor's degree	1087 (16.1%)	
Diabetes Status			
	No diabetes	3620 (53.8%)	
	Type 1 diabetes	497 (7.4%)	
	Type 2 diabetes	2613 (38.8%)	
Goal Presentation			
	Standard Range only	2253 (33.3%)	
	Goal Range added	2219 (32.8%)	
	Goal Range only	2294 (33.9%)	
A1c Test Result			
	6.2%	3390 (50.1%)	
	8.2%	3376 (49.9%)	
Display Format			
	Table	2251 (33.3%)	

Simple Line	2224 (32.9%)
Block Line	2291 (33.9%)

Note: Reports result only for those respondents who completed each question or measure
[a]Respondents could mark more than one race.

Figure 2. Effect of providing goal range information in table format, by goal presentation type and A1c test result.



Note: Asterisks indicate statistically significant differences between the two bars.

significantly increased the percentage of participants recognizing that their A1c=6.2% value was below the goal range ($\chi^2(2)=126.90$, $P<.001$) and stating that their next result should be higher ($\chi^2(2)=36.03$ $P<.001$). Furthermore, the effect was larger among participants who viewed a table with the goal range only vs. when the goal range

was added to the standard range (Relative location: goal range only: 51.3% vs. goal range added: 44.2%, $\chi^2(1)=3.76$, $P=.053$; Future location: goal range only: 47.0% vs. goal range added: 37.4%, $\chi^2(1)=7.01$, $P=.008$). Similarly, providing goal information (either format) in table displays reduced discouragement ($F(2, 1071)=19.38$, $P<.001$) and urgency ($F(2, 1131)=3.09$, $P=.046$) compared to no goal displays although there was no significant difference between the goal range added vs. goal only conditions.

The logistic regression analyses of participants receiving test results in table format (Table 2) confirmed significant main effects for A1c test value and goal presentation for all four outcome measures (all Ps$<.001$), with the exception of goal presentation for urgency which became non-significant when controlling for the covariates, $\chi^2(2)=5.50$, $P=.064$. Consistent with the pattern seen in Figure 2, there were significant interactions between A1c test value and goal presentation for relative location, $\chi^2(2)=62.83$, $P<.001$, future location, $\chi^2(2)=11.4$, $P=.003$, and discouragement, $\chi^2(2)=7.24$, $P=.027$, but not for urgency, $\chi^2(2)=1.24$, $P=.539$. In addition, individuals with diabetes had a lower likelihood of identifying the relative location, but also lower discouragement, relative to individuals without diabetes. Being older and female were associated with an increased likelihood of identifying the relative location, but decreased urgency. Additionally, being older was associated with increased discouragement while identifying as female was associated with an increased likelihood of correctly identifying where their next test result should be. Identifying as a person of color (non-White) was associated with

Table 2. Logistic regression and ordered logistic regression results showing predictors of outcome measures, Table condition only.

	Relative location	Future location	Discouraged	Urgency

	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Goal presentation				
Standard Range only	ref	ref	ref	ref
Goal Range added	4.98***	1.69***	0.51***	0.77*
	(3.46, 7.17)	(1.23, 2.32)	(0.39, 0.67)	(0.59, 1.00)
Goal Range only	6.83***	2.52***	0.47***	0.74*
	(4.77, 9.76)	(1.86, 3.42)	(0.35, 0.59)	(0.57, 0.95)
A1c test result				
6.2%	ref	ref	ref	ref
8.2%	12.07***	4.30***	4.13***	2.16***
	(8.30, 17.54)	(3.13, 5.91)	(3.12, 4.46)	(1.63, 2.86)
Goal x A1c				
Goal Range added x	0.25***	0.57**	1.40	1.24
8.2%	(0.15, 0.40)	(0.37, 0.87)	(0.95, 2.05)	(0.84, 1.84)
Goal Range only x	0.15***	0.49***	1.67**	1.16
8.2%	(0.09, 0.24)	(0.32, 0.75)	(1.15, 2.44)	(0.79, 1.71)
Demographics				
Diabetes	0.64***	1.03	0.52***	0.98
	(0.52, 0.77)	(0.87, 1.23)	(0.44, 0.61)	(0.84, 1.15)
Age	1.02***	1.00	1.01***	0.98***
	(1.01, 1.03)	(0.99, 1.00)	(1.01, 1.02)	(0.97, 0.99)
Female Gender	1.74***	1.03*	1.16	0.84*
	(1.44, 2.11)	(1.03, 1.47)	(0.99, 1.35)	(0.72, 0.99)
Race	0.70**	1.00	1.01	1.08
	(0.56, 0.87)	(0.81, 1.24)	(0.84, 1.22)	(0.90, 1.32)
Education	1.11***	1.03	0.99	1.08***
	(1.05, 1.17)	(0.98, 1.08)	(0.94, 1.03)	(1.04, 1.13)
Constant	0.03***	0.28***		
	(0.02, 0.05)	(0.16, 0.47)		

Note: OR, odds ratio; CI, confidence interval. Diabetes (0=No, 1=Yes); gender (0=Male, 1=Female); race (0=White, 1=non-White); age and education treated as continuous variables. *p≤.05 **p≤.01 ***p≤.001

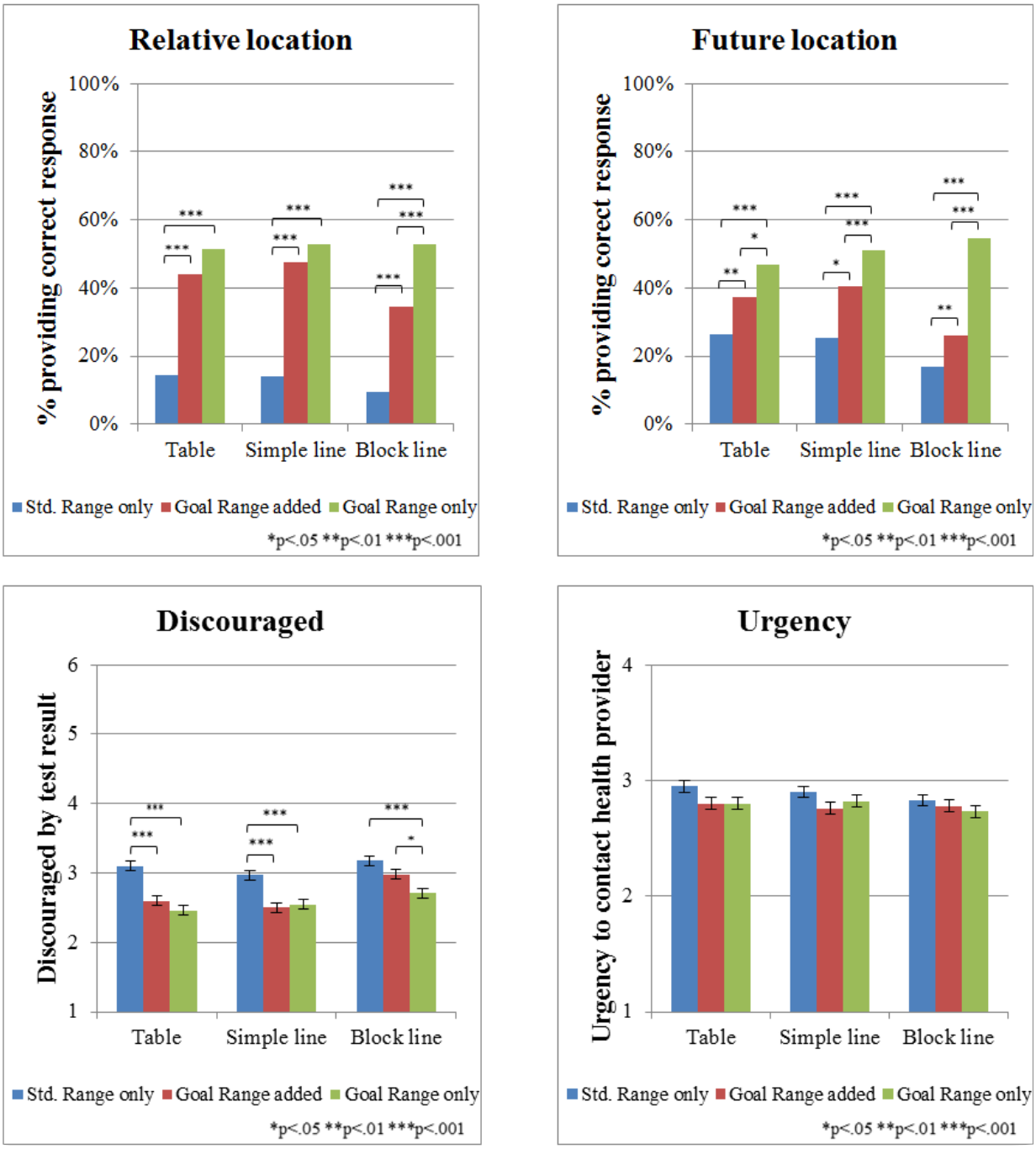
a decreased likelihood of identifying the relative location. Higher education was associated with improved comprehension of the relative location, but also increased urgency.

Impact of display format on goal presentation, A1c=6.2% condition only

Given that providing goal information to participants receiving test results via tables only influenced outcomes among those viewing A1c=6.2% results, we focused only on these conditions when comparing optimal formats (i.e., Table vs. Simple Line vs. Blocks line) for presenting goal information.

As shown in Figure 3, the overall pattern of goal presentation results on understanding and interpretation of A1c=6.2% results in the Simple Line and Block Line conditions mirrored the pattern discussed above for the Table format: Providing goal information (in any format) increased the percentage of participants recognizing that their A1c value was below the goal range, wanting their next result to be higher, and experiencing less discouragement. There were, however, minor differences with the Block Line design. Compared to the Table and Simple Line designs where the goal range was added, participants in the Block Line condition exhibited less comprehension of their goal location ($\chi^2(2)=13.86$, $P<.001$) and where their next test result should be ($\chi^2(2)=19.40$, $P<.001$), as well as greater discouragement $F(2, 1026)=11.42$, $P<.001$). The logistic regression analyses (see Table 3) revealed main effects of goal presentation (all Ps≤.002), with participants in the Goal Range Added and Goal Range Only conditions having higher comprehension and less discouragement and urgency compared to participants in the no goal condition, and display type (Ps≤.002 for relative location, future location, and discouragement measures). More interestingly, there were also significant interactions between goal presentation and display format for relative location, $\chi^2(4)=11.63$, $P=.020$, and future location, $\chi^2(4)=22.24$, $P<.001$, but not discouragement, $\chi^2(4)=7.98$, $P=.092$, or urgency,

Figure 3. Effects of presenting goal information to patients viewing an A1c=6.2% test result, goal presentation and display format.



Note: Asterisks indicate statistically significant differences between the two bars.

$\chi^2(4)=3.18$, $P=.528$. As noted earlier, the Block Line design seemed to interfere with the efficacy of including goal information when the standard range was also present (see Figure 3).

Demographic covariates remained significant predictors across the four outcome measures (see Table 3). People with diabetes were less likely to identify the relative location of their result say that the A1c=6.2% result should be higher, but they also had less discouragement and urgency relative to individuals without diabetes. Age produced inconsistent effects, with high comprehension of relative location, but less comprehensions of future location, along with lower discouragement and urgency. Identifying as Female or White were both associated with increased comprehension of relative location and with decreased urgency. Education was associated with increased comprehension of relative location.

Interaction analysis of the impact of diabetes status, A1c=6.2% condition only

The regression results in Table 3 showed consistent main effects when comparing participants who have diabetes in real life versus those who did not. To explore whether diabetes status might interact with optimal display formats, we ran additional regression analyses including interaction terms based on diabetes status. These additional logistic regression and ordered logistic regression results (see Appendix Table 1) revealed a significant interaction between diabetes status and goal presentation for comprehension of the relative and future locations (Ps<.001), but not for discouragement and urgency (Ps>.15). For comprehension of relative location, the overall relationship between the effect of goal presentation did not change based on whether someone had diabetes (no goal: 14.5% vs. goal range added: 35.9%; and goal range only: 43.5%; Ps<.001) or not (no goal: 11.2% vs. goal range added: 46.7%; and goal range only: 59.6%; Ps<.001), the effects were just more exaggerated for people without diabetes. For

comprehension of the future location, there were significant differences between all three goal presentation conditions for participants without diabetes (no goal: 22.8% vs. goal range added:

Table 3. Logistic regression results showing goal presentation, presentation format, and demographics as predictors of outcome measures, 6.2% A1c test value condition only.

	Relative location	Future location	Discouraged	Urgency
	OR (95% CI)	OR	OR	OR
Goal presentation				
Standard Range only	ref	ref	ref	ref
Goal Range added	4.85***	1.73***	0.45***	0.74*
	(3.38, 6.96)	(1.25, 2.39)	(0.34, 0.59)	(0.56, 0.96)
Goal Range only	6.62***	2.65***	0.39***	0.72*
	(4.65, 9.44)	(1.94, 3.63)	(0.30, 0.51)	(0.55, 0.93)
Presentation format				
Table	ref	ref	ref	ref
Simple Line	1.02	1.01	0.85	0.92
	(0.68, 1.54)	(0.73, 1.42)	(0.65, 1.11)	(0.71, 1.20)
Block Line	0.61*	0.60**	1.17	0.83
	(0.39, 0.97)	(0.41, 0.86)	(0.90, 1.53)	(0.64, 1.08)
Goal x Presentation				
Goal Range added x	1.17	1.17	1.16	0.99
Simple Line	(0.70, 1.95)	(0.73, 1.85)	(0.78, 1.70)	(0.68, 1.46)
Goal Range added x	1.07	1.02	1.56*	1.22
Block Line	(0.62, 1.86)	(0.63, 1.67)	(1.07, 2.28)	(0.83, 1.78)
Goal Range only x	0.99	1.19	1.36	1.20
Simple Line	(0.60, 1.64)	(0.76, 1.86)	(0.94, 1.97)	(0.83, 1.74)
Goal Range only x	1.74*	2.32***	1.29	1.09
Block Line	(1.01, 2.99)	(1.45, 3.71)	(0.89, 1.86)	(0.76, 1.58)
Demographics				
Diabetes	0.64***	0.77***	0.31***	0.74***
	(0.55, 0.75)	(0.66, 0.89)	(0.27, 0.35)	(0.65, 0.84)
Age	1.01***	0.97***	1.00*	0.97***
	(1.01, 1.02)	(0.96, 0.97)	(0.99-1.00)	(0.97, 0.98)
Female Gender	1.56***	0.90	1.04	0.79***
	(1.33, 1.82)	(0.77, 1.05)	(0.91, 1.18)	(0.69, 0.89)
Race	0.76**	1.02	0.96	1.20**
	(0.63, 0.92)	(0.85, 1.22)	(0.82, 1.12)	(1.03, 1.40)
Education	1.11***	1.04	0.98	1.02
	(1.06, 1.16)	(1.00, 1.09)	(0.95, 1.02)	(0.99, 1.06)
Constant	0.04***	1.38		
	(0.03, 0.07)	(0.87, 2.19)		

Note: OR, odds ratio; CI, confidence interval. Diabetes (0=No, 1=Yes); gender (0=Male, 1=Female); race (0=White, 1=non-White); age and education treated as continuous variables. *p≤.05 **p≤.01 ***p≤.001

Appendix Table 1. Logistic regression and ordered logistic regression results showing goal presentation, diabetes status, and demographics as predictors of outcome measures, 6.2% A1c test value condition only

	Relative location	Future location	Discouraged	Urgency
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Goal presentation				
Standard Range only	ref	ref	ref	ref
Goal Range added	7.26***	2.48***	0.57***	0.71**
	(5.32, 9.92)	(1.91, 3.23)	(0.46, 0.71)	(0.57, 0.89)
Goal Range only	12.37***	4.84***	0.50***	0.68***
	(9.08, 16.87)	(3.73, 6.27)	(0.41, 0.61)	(0.55, 0.84)
Diabetes Status				
No diabetes	ref	ref	ref	ref
Diabetes	1.31	1.25	0.33***	0.63***
	(0.91, 1.87)	(0.94, 1.66)	(0.26, 0.41)	(0.51, 0.78)
Goal x Presentation				
Goal Range added x Diabetes	0.47***	0.48***	0.98	1.21
	(0.30, 0.73)	(0.32, 0.71)	(0.72, 1.33)	(0.88, 1.65)
Goal Range only x Diabetes	0.37***	0.54***	0.91	1.34
	(0.24, 0.57)	(0.37, 0.78)	(0.67, 1.23)	(0.99, 1.81)
Demographics				
Age	1.01***	0.97***	1.00	0.97***
	(1.01, 1.02)	(0.96, 0.97)	(0.99, 1.00)	(0.97, 0.98)
Female Gender	1.57***	0.91	1.03	0.78***
	(1.34, 1.84)	(0.78, 1.06)	(0.91, 1.17)	(0.69, 0.89)
Race	0.77**	1.03	0.95	1.20*
	(0.63, 0.93)	(0.86, 1.24)	(0.82, 1.11)	(1.03, 1.40)
Education	1.11***	1.04	0.98	1.03
	(1.07, 1.17)	(1.00, 1.09)	(0.95, 1.02)	(0.99, 1.06)
Constant	0.03***	0.97		
	(0.02, 0.04)	(0.63, 1.49)		

Note: OR, odds ratio; CI, confidence interval. Diabetes (0=No, 1=Yes); gender (0=Male, 1=Female); race (0=White, 1=non-White); age and education treated as continuous variables. *p≤.05 **p≤.01 ***p≤.001

40.2%; and goal range only: 56.1%; *P*s<.001). However, for people with diabetes, comprehension was significantly higher in the goal only condition (44.5%) compared to the no goal (23.2%, *P*<.001) and goal range added (26.7%, *P*<.001) conditions, while there were no significant differences between the no goal and goal range added condition, *P*=.701.

Discussion

Our data suggest that providing people with test results displays (tabular or visual) that include goal range information can alter their perceptions of their test results in important ways. While perceptions were generally unaffected by format when the result was above both standard and goal ranges, perceptions were sensitive to format when the result was above the standard range but below the goal range. Comprehension of the below-target nature of this result was higher when goal information was explicitly included in their test result tables or visual displays. Furthermore, inclusion of goal information in the display reduced perceived discouragement about the presented results.

Our data also show that removing the standard range and instead substituting a single goal reference range seems superior to simply adding goal range information along with the standard range values. Comprehension was highest and discouragement and urgency were lowest when the goal range information was presented in lieu of the standard range information. This suggests that it is difficult for people to put aside information about the standard range—which is normed based on the total, mostly healthy, population—even when more personalized goal information is easily available. As a result, inclusion of these standard reference points (which are less relevant in this particular situation) may undermine patients' ability to manage their chronic conditions and may expose them to harm when aggressively trying to get test results to the standard range [6–9].

Fundamental principles of both visual design and information evaluability suggest that the dominance of the goal only substitution condition is due to the fact that the inclusions of more than one reference range produces confusion about which comparator is most relevant to understanding where the patient's test value should be [15,16]. This argument is bolstered by the fact that, among the conditions where goal information was presented in addition to the standard range, comprehension was lowest and discouragement was highest when participants received block design visuals. This design already includes multiple color-coded sections and categorical labels indicating levels of risk, and adding yet another reference range for patients to interpret at the same time was clearly too much for many to handle.

One limitation of our study is the use of a hypothetical scenario. While participants did not receive actual test results, approximately half of our sample had the medical condition described in the scenario (diabetes) and would likely have experience receiving A1c test results. While we found the same pattern of results for participants with and without diabetes, participants with diabetes who received A1c=6.2% results were less likely to report that their values were too low, but these participants also exhibited decreased discouragement and urgency. One possible explanation for this finding, is that their experience with repeatedly being told that their A1c goal should be below 7.0% has led them to led them to adopt the standard range as the norm that they should be striving to attain, even when an alternative goal range has been provided. Another possibility is that participants with diabetes were relying on their real-life goal ranges, which may have been different than the one provided in the scenario, or that they recognize that not all persons with type 2 diabetes will experience adverse outcomes with an A1c of 6.2%. This explanation may account for the overall smaller percentage of participants with diabetes who

were discouraged about their test result or felt a need to contact their health care provider immediately.

As more and more patients receive their test results via online patient portals, it is becoming increasingly important that patients be able to find their results meaningful and that we do not cause unnecessary distress or discouragement to patients. Current approaches to presenting laboratory test results to patients appear to be particularly problematic for many patients, such as those with chronic conditions, who may have personal target goals that differ from those relevant to healthy adults. For these patients, the standard range commonly shown is not necessarily where we want patients to be. Providing goal range information in place of the standard range may be one step towards reducing these problems with EHR systems, although challenging discussions would need to occur regarding the pros and cons of who should determine the goal range information (i.e., health systems, EHR/portal vendors, expert panels, individual physicians, and/or patients) or what the goal ranges represent (e.g., goals for people with chronic condition broadly versus individualized goals). More research is needed to determine additional features that may further improve the interpretability of laboratory test results.

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Conflicts of Interest

None declared.

Abbreviations

EHR: Electronic Health Record

SSI: Survey Sampling International

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