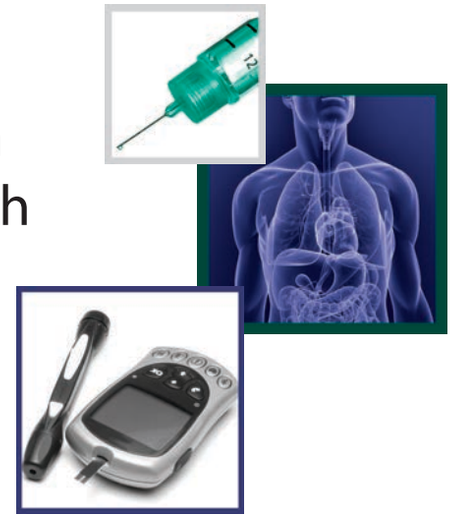
RESEARCH ARTICLE

Pen colors facilitate the differentiation of SoloSTAR® insulin pens by users with normal and impaired color vision



Steve Chasin*[1] & Linda Morrissey[1]

Practice Points

- Diabetic retinopathy is thought to affect approximately a third of people with diabetes and affects both visual acuity and color perception.
- Visual impairment may increase the risk for medication errors.
- SoloSTAR® is a prefilled insulin pen for insulin glargine and insulin glulisine administration.
- Two models of SoloSTAR were developed with various differentiating features to distinguish between insulin glargine and insulin glulisine.
- This study, conducted as a survey, evaluated the potential for successful differentiation under normal and low-lighting levels, and by people with color vision deficiencies.
- Analysis of human factors confirmed that the two colors of the pen body and injection button for both pens were different for all color features (hue, saturation and brightness).
- Of the 103 respondents, 99% could correctly identify both pens.
- This study confirmed that SoloSTAR pens can be differentiated according to both human factor evaluation and by people with impaired color vision.
- The ease of differentiation between SoloSTAR pens should reduce the risk of medication errors.

SUMMARY **Aims:** SoloSTAR® is a prefilled insulin pen for insulin glargine or insulin glulisine administration, with specific body-color features to aid differentiation. The aim of this study was to evaluate the potential for differentiating the two insulin pens by specialists of human factors with normal vision, taking into consideration a number of human-factor requirements for successful color differentiation. These findings were then validated in people with impaired color vision. **Materials & methods:** This two-phase study involved research in human factors, in which the pen body, label and injection buttons of the two pens were compared, and face-to-face surveys of 103 respondents with impaired color vision was carried out, as determined by the Ishihara color blindness test. **Results:** Analysis of human factors confirmed that the two colors of the pen body and injection button for both pens were different for all color features (hue, saturation and brightness). In the survey, 99% of the respondents correctly identified both pens, with the majority being able to

[1]Lieberman Research Group, 98 Cutter Mill Road, Great Neck, NY, USA
*Author for correspondence: Tel.: +1 516 829 8880; Fax: +1 516 829 9419; chasins@liebermanresearch.com

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differentiate color (95%), label (94%), name (99%), feel of the dose knob buttons (95%) and contrast (97%). Furthermore, 85% of the respondents correctly differentiated between the pens based on all five characteristics. Only five respondents (5%) reported the two pens to have the same body color. **Conclusion:** The results of this two-phase study confirmed that the SoloSTAR® pens can be differentiated based on their different body colors according to specialist evaluation of human factors and by people with impaired color vision. The ability to differentiate between the SoloSTAR pens should reduce the risk of medication errors.

Diabetes retinopathy is a relatively common complication thought to affect approximately 30% of people with diabetes [1]. In the USA, it is estimated that the number of people with diabetes and diabetic retinopathy was 5.5 million in 2005 and will increase to 16 million by 2050 [2]. Retinopathy affects both visual acuity and color perception, owing to a reduction of light falling on the retina and the death of cones where the oxygen supply is restricted [3]. The extent of visual impairment in the diabetes population may vary, ranging from macular edema, which causes a loss of visual acuity, to proliferative diabetic retinopathy, which can ultimately lead to complete loss of vision [3]. In addition to acquired impaired visual acuity, congenital conditions that affect sight can also afflict patients with diabetes, such as color blindness, which manifests as an inability to differentiate between specific colors, depending on the retinal cones affected [4].

In patients with diabetes, for whom daily self-administered treatment regimens are commonplace, impaired visual acuity can negatively impact treatment practices and health outcomes [5,6]. Indeed, the majority of people with Type 1 diabetes, and an increasing number of those with Type 2 diabetes, inject both long- and rapid-acting insulins to manage basal and prandial insulin requirements [7]. Visual problems may increase the risk for medication errors, such as injecting a rapid-acting insulin instead of a long-acting insulin, which have markedly different pharmacokinetic and pharmacodynamic profiles, due to selection of the wrong insulin or injection device [8–10]. To help diabetic patients and healthcare professionals in selecting and injecting the correct type of insulin, insulin pens can be differentiated according to the insulin they contain via design features such as the text on the label of the pen, the colors of the label and the dose button and/or differentiating tactile features on the dose injection button [11–13].

SoloSTAR® (Sanofi, NJ, USA) is a prefilled disposable insulin pen that contains either insulin glargine (LANTUS®, Sanofi), a once-daily, long-acting insulin or insulin glulisine (Apidra®, Sanofi), a rapid-acting insulin administered before or shortly after a meal **(Figure 1)** [101–104]. Two models of SoloSTAR were developed with various differentiating features to distinguish between the two insulins: body color and injection-button color (grey for insulin glargine; and blue for insulin glulisine), tactile features and labels (color, layout and text).

The objectives of this study were to evaluate the potential for differentiating the two insulin pens on the basis of requirements of human factors for successful color differentiation under normal and simulated conditions (including low lighting levels) and in types of color vision deficiencies by human-factor specialists with normal vision, and to validate the findings in simulated conditions by people with impaired color vision.

Research design & methods

This two-phase study involved research of human factors and a survey of people with color blindness.

■ Phase I: human-factors research

The color differentiation research focused on the three color dimensions: hue (perceptual quality of light of different wavelengths), saturation (the 'purity' of a hue, which is reduced as more black, grey or white is introduced into the hue) and brightness (the amount of light reflected by a surface). Two specialists of human factors with normal color vision conducted a subjective evaluation of the insulin glargine and insulin glulisine pens under normal daylight conditions. The pen analysis was divided into three separate components: pen body, label and injection button, and the color combinations were assessed and scored in terms of hue, saturation and brightness (**Supplementary Material**, **Appendix 1**, see online: www.futuremedicine.com/doi/suppl/10.2217/dmt.12.61).

Scores for each component were totalled, and a minimum combined score of six points was considered to represent sufficient color differentiation; to reach this score, each pen

combination had to allow the user to differentiate on at least two dimensions across all three components. The assessment was supported by hue, saturation and brightness values associated with Pantone® (Pantone LLC, NJ, USA) reference colors for the insulin color codes and estimated values for the pen body colors.

The analysis of human factors was followed by a simulation, in which the insulin pens were visualized under different lighting conditions and with filters that approximate the types of color deficiencies using Vischeck software in combination with Adobe and JASC Photoshop software.

■ Phase II: user assessment in people with impaired color vision

To validate the findings of the human-factors research, a user study was performed by an independent research company and involved people with impaired color vision including those with self-reported diabetes. Face-to-face interviews were conducted in shopping malls in ten geographically dispersed regions across the USA, including areas in the northeast, southeast, central and mountain/pacific regions.

Eligibility

Potential respondents were screened to determine their eligibility **(Supplementary Material, Appendix 2)** and were excluded if they or an immediate family member were currently employed, were a paid consultant or were a clinical researcher for any pharmaceutical manufacturer or their agents, a paid consultant for a government health-related agency or an advertising agency, a physician, nurse, or paid by a public relations or marketing research agency. Additional exclusion criteria included participation in any market research in the past 3 months. All respondents had impaired color vision, as determined using the Ishihara color test **(Supplementary Material, Appendix 2)**. Written, informed consent was not required.

Assessment procedure

Eligible respondents were escorted to a well-lit office setting in the mall where the main part of the survey was conducted. A respondent was given the insulin glargine and insulin glulisine pens by the interviewer, and were asked to identify them using a nine-question survey **(Supplementary Material, Appendix 3)**, which assessed their ability to differentiate between the two pens, focusing on the following aspects: whether the respondent could correctly identify each of the two pens; whether the respondent could determine if the pens were the same or different on physical characteristics of color, label (words, as well as color, shape and design), name (on the label), feel of the dose knob buttons and contrast (i.e., how dark or light they were in comparison); and whether the respondent could distinguish the color of the insulin glargine pen and the insulin glulisine pen. After the evaluation, the respondent's demographic information was recorded.

Results

■ Phase I: human-factors research study

The research of human factors showed that the label colors, injection button colors and dose button colors were sufficiently dissimilar to differentiate between the two pens. For the pen body, label and injection button, a maximum component combination of nine points was scored, which was above the threshold score of six points judged as necessary for providing sufficient differentiation.

The pen body color represents the largest colored area on the pens, and for the insulin glargine and insulin glulisine pens, these were

Figure 1. Image of Lantus® SoloSTAR® and Apidra® SoloSTAR as used in the study. Actual pens rather than images were used in the study. The Apidra SoloSTAR pen as approved by the US FDA has a slight variation in the label from the version shown here.

sufficiently different across all three dimensions of color (hue, saturation and brightness). This includes differentiating under various lighting conditions for users with normal color vision and for those with simulated color vision deficiencies. In addition, the label was sufficiently differentiated by color and layout, including pattern and shape, with LANTUS and Apidra brand and generic names clearly visible on each pen.

■ Phase II: survey

The respondents' characteristics are listed in Table 1. A total of 103 surveys were conducted in individuals with impaired color vision. Of these, 21 also had self-reported diabetes (with seven and 14 respondents with Type 1 or Type 2 diabetes, respectively). Overall, 99% (n = 102) of respondents correctly identified the insulin glargine and insulin glulisine pens, with more than 94% of respondents able to differentiate the physical characteristics, including color (95%), label (94%), name (99%), feel of dose button (95%) and contrast (97%) (Figure 2A). In differentiating the pens, 2, 1 and 12% of respondents were able to distinguish between them based on two, three or four characteristics, respectively, while the majority of respondents (85%) could distinguish between the pens based on all five characteristics (Figure 2B). Of these, three respondents had self-reported Type 1 diabetes and ten respondents had self-reported Type 2 diabetes.

Table 1. Respondent characteristics (Phase II).

Characteristics	Value
Total (n)	103
Male/female (%)	29/71
Respondents with diabetes (n)	21
▪ Type 1	7
▪ Type 2	14
Treatment (n)	
▪ Insulin	10
▪ Oral agents	10
No pharmacological treatment (n)	1
Method of insulin administration (n)	
▪ Vial and syringe	5
▪ Insulin pen	5
Self-injection (n)	10
Age (%)	
▪ 18–49 years	67
▪ 50+ years	33
Using glasses/corrective lenses (n)	39
▪ Needed for reading only (n)	30
Physical impairments (self-reported fine-motor impairment) (n)	12

Overall, the pens were reported to be the same in terms of color by five respondents, label by six, name by one, feel of the dose button by five and contrast by three.

Discussion

SoloSTAR is the first and currently the only prefilled insulin device to differentiate between short- and long-acting insulins using distinct body colors. Research of human-factors findings (Phase I) from this study indicated that pen body, label and injection button color choices for the insulin glargine and the insulin glulisine SoloSTAR pens differed sufficiently, and that it should be possible for the two pens to be differentiated by people with normal vision under normal or low lighting conditions and by people with impaired color vision. In the survey among people with impaired color vision (Phase II – determined by the Ishihara color blindness test), the majority of respondents (99%), of whom 20% had self-reported diabetes, were able to differentiate between the pens on at least two out of five characteristics (i.e., body color, label, name, feel of dose buttons and contrast). All but one respondent correctly identified the two pens; however, after re-evaluating the physical characteristics, this person was able to correctly identify the pens when asked a second time.

The ability to differentiate between insulin pens irrespective of user color vision status minimizes the risk of administering the wrong treatment and consequential adverse events. Body color is the largest colored area present on the pen and is likely to be visible at all stages of pen use, whereas the label and text may be obscured by the hand while operating the pen, thus, sufficient differentiation is required for this key component. It is important to remember, however, that while color differentiation provides a visual cue to prevent confusion and medication errors, individuals with impaired color vision may rely on another mode of sensation, such as touch, to offset this constraint. Thus, this research is of particular relevance in the clinical management of diabetes in people with limited visual acuity related to congenital color blindness or acquired impaired color vision associated with diabetic retinopathy, as disease progression means that diabetes patients will often ultimately use two types of insulin (e.g., basal and prandial).

The results of the study should be interpreted in conjunction with its limitations, primarily that prefilled insulin pens from other

manufacturers were not included for comparison (e.g., FlexPen® [Novo Nordisk A/S, Bagsvaerd, Denmark], KwikPen® [Eli Lilly and Co., IN, USA] and Eli Lilly original prefilled pen), or any reusable pens (e.g., ClikSTAR® [Sanofi], NovoPen® [Novo Nordisk A/S] and Luxura® [Eli Lilly and Co.]). The study was of a small scale, with only two human-factor specialists and 103 respondents involved. Furthermore, although the majority of enrolled respondents did not have self-reported diabetes, this was not medically confirmed and it is possible that some of these had undiagnosed diabetes. Thus, the inclusion of a diabetes screening test would be of benefit to future studies. Similarly, with regard to the respondents with diabetes, the study did not determine the cause of their impaired color vision; in particular, whether this was due to diabetic retinopathy or a congenital cause. A further limitation of the study was that during Phase II, respondents were asked to make an assessment with both pens in view, which may have influenced the success rates positively or negatively. If only a single pen had been presented during Phase II, the test may have been more difficult as the comparator for differentiation would not be present and respondents would have to rely more on their memory. Finally, the lighting conditions used in both phases of this study may not represent the ambient lighting conditions under which some people with diabetes might use the pen. However, the lighting levels used were considered to broadly reflect typical levels of illumination.

Future studies focusing on different populations, either more diverse or more focused (e.g., with diabetic retinopathy) would be of interest, as would including other pen devices in the assessment, and would help to confirm whether the findings presented in this study can be generalized to a broader population of people with diabetes.

The results of this study could reassure diabetes patients and healthcare professionals that the two SoloSTAR insulin pens can be easily differentiated, as well as by people with impaired color vision.

Author contributions

The authors contributed to the study design, data collection and analysis during Phase II of this study, and critical review and revision of the manuscript at each stage of development. The authors also gave final approval of the submitted version of the manuscript.

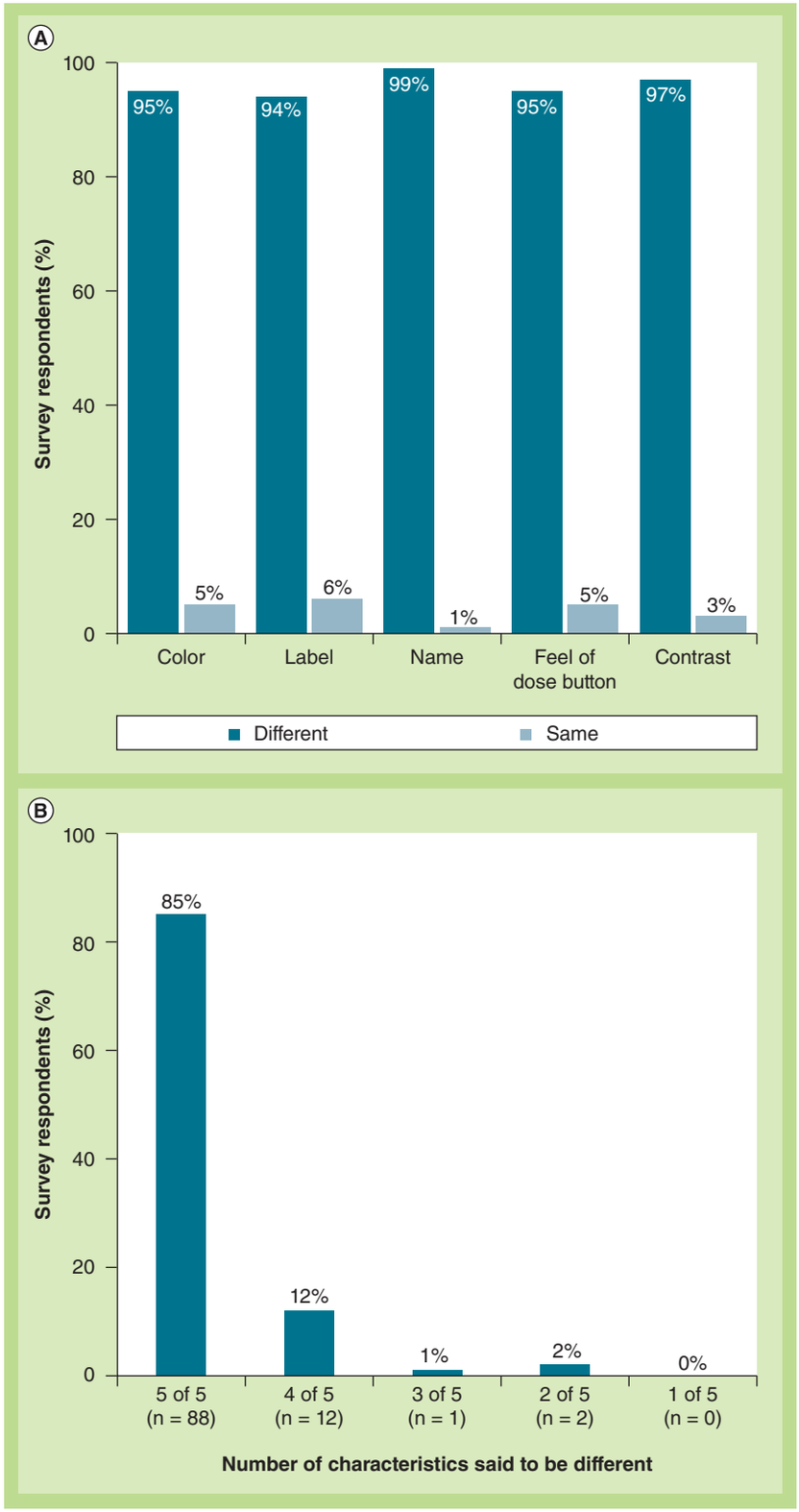

Figure 2. Percentage of survey respondents differentiating the insulin glargine pen and the insulin glulisine pen. (A) Physical characteristics and **(B)** the number of different physical characteristics (Phase II).

Financial & competing interests disclosure

L Morrissey and S Chasin are employees of the Lieberman Research Group, an independent research group that received funding to carry out this study from Sanofi. The human-factors research (Phase I) was conducted by Human Engineering Services. The survey (Phase II) was conducted by an independent research group (Lieberman Research Group). Both phases of the study were supported by Sanofi. The authors have no other relevant affiliations or financial involvement with any organization or entity with a financial interest in or financial conflict with the subject matter or materials discussed in the manuscript apart from those disclosed.

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Ethical conduct of research

The authors state that they have obtained appropriate institutional review board approval or have followed the principles outlined in the Declaration of Helsinki for all human or animal experimental investigations. In addition, for investigations involving human subjects, informed consent has been obtained from the participants involved.

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