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Investigation of Visual Requirements for Change Detection

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INVESTIGATION OF VISUAL REQUIREMENTS FOR CHANGE DETECTION

by

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ABSTRACT

In this study, participants performed a change detection task. Specifically we examined whether participants had to fixate on a difference between two images before they could detect it. Thirty-six participants performed a change detection task in either a 3 minute or a 1.5 minute condition. We found a significant interaction between task duration and fixation type (whether the participant had fixated on the difference in both, one, or neither image). Participants found a greater number of differences given more time only when they fixated on the difference in both images. The number of differences which were detected by participants with a fixation on only one image or on neither image did not increase with a corresponding increase in time, indicating that some mechanical error may be involved. This suggests that participants need to fixate on a difference before being able to detect it.

Keywords: fixation, change detection, change blindness

ACKNOWLEDGEMENTS

Thank you to Dr. Hancock, Dr. Sims, and Dr. Cash for making this project possible. Also, thank you to Ben for guiding me through every step, and answering my questions, even if your answer was, “I don’t know.” Thank you Jessica for being like a big sister and doing everything before me so I could watch and learn. Many thanks to Petal, Daniellys, Daniel, Steve, and all my other friends and helpers at the MIT2 Lab. Vielen Dank Eva für ermutigte mich, meine Forschungen fortzusetzen. Finally, thank you Stephen for telling me I could when I believed I couldn’t.

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INTRODUCTION

Consider for a moment how rich the human visual experience is. A person can distinguish objects from the background and perceive various characteristics about those objects such as color, texture, size, and distance from one's self with just a glance. Despite the vividness of this experience, the visual system has a number of limitations. For instance, unlike a photograph, which is equally detailed at both the edges and the center, the image captured by the eye is highly detailed only at the center of the visual field. The greatest visual acuity is captured by the anatomical structure called the fovea, which occupies approximately 0.01% of the area of the visual field (Schwartz 2010). As shown in Figure 1, beyond the foveal region, visual acuity dramatically drops to about 30% just 10° from the fovea (Foley & Matlin 2010).

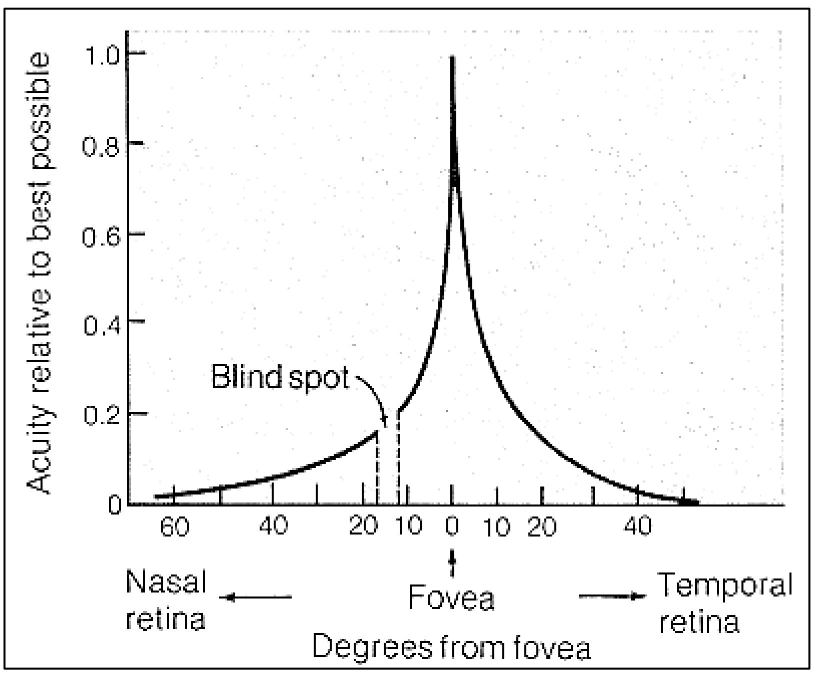

Figure 1: Visual acuity across visual field

Source: Foley & Matlin 2010.

Even though visual acuity is unevenly distributed across the visual field, the world is still perceived as perfectly acute, a phenomenon referred to as the "grand illusion" (Noë, Pessoa, & Thompson 2000). The apparent clarity is facilitated by eye movements called saccades, which allow the eye to momentarily fixate on numerous locations across the visual field. A mental representation is constructed from the information in these fixations (Enns & Austen 2007). However, this representation is not a detailed map of the visual field; rather it contains only the central themes of a scene. Any specific details are remembered only for a short time before fading into this "gist" (Hayhoe, 2007). If a detail which did not affect the gist were to change, it might go unnoticed. The failure to detect such a change to an object or scene is called change blindness (Simons & Levin 1997; Wilson & Goddard 2011).

Some of the earliest evidence of change blindness comes from research on visual short term memory. In a study by Phillips (1974), participants were shown a matrix of light and dark squares followed by an interstimulus interval (ISI) and then a second matrix, which was either identical or very similar to the first matrix. Participants were instructed to determine whether the matrix had changed. Even with ISI durations as short as 40 milliseconds, participants experienced difficulty detecting whether a change had occurred. More evidence for change blindness emerged in research regarding the integration of visual information from numerous saccades. McConkie and Zola (1979) had participants read passages in which the letters alternated case (ThE qUiCk BrOwN fOx). During certain saccades, the case of each letter was switched (tHe QuIcK bRoWn FoX), but reading performance was unaffected and participants did not notice the change.

More recently the study of change blindness has been used as a method for studying various aspects of visual perception such as the nature of mental representations. In many cases, change blindness seems to indicate that mental representations are rather sparse (Simons & Levin 1998). Noë, Pessoa, and Thompson (2000) point out that various failures in the process of visual perception would produce the effects of change blindness. In other words, detailed mental representations may exist, but decay over time or are unavailable or unusable for change detection (Simons & Rensink 2005). A growing amount of research suggests that, to an extent, all of these are valid explanations for change blindness. Wilson and Goddard (2011) found that as participants received a cue at a later points after the initial stimulus disappeared, performance in detecting a change to the stimuli declined. This suggests that mental representations decay over time. If they didn't, the delay between stimulus offset and cue would not affect performance. In a study by Mitroff, Simons, and Levin (2004) Participants were able to identify items from pre-and post- change stimuli even if they failed to actually detect the change, supporting the hypothesis that the information regarding the pre- and post- change stimuli existed, but that a failure to compare this information occurred.

Change blindness has also been used as a method for studying the effects of attention on visual perception (Simons & Rensink 2005). O'Regan, Deubel, Clark, and Rensink (2000) tracked participants' eye movements while they performed a change detection task and found that even if the participants fixated within 1° of a change, they would still fail to detect the change more than 40% of the time. This indicates that having the visual information available is not sufficient for change detection, but that focused attention is necessary as well. Austen and Enns (2000) found that participants more easily detected changes made on a global level (big

picture) than on a local level (little details). They suggest that paying attention to a scene at a global level may be the default of human visual perception. However, this default seems to be affected by expertise. Werner and Thies (2000) demonstrated that football experts detected changes to football scenes which novices did not notice. In other research, Rensink, O'Regan, and Clark (1997) found that participants more easily detected changes made to objects of central interest than of marginal interest, which points to the fact that certain objects in a scene are more attention-drawing than others.

Change blindness has also become a topic of intense study in its own right (Simons & Levin 1997; Turatto, Bettella, Umiltà, & Bridgeman 2003). One of the most spectacular examples of change blindness was produced during an experiment conducted Simons and Levin (1998). In this experiment, a confederate of the research team asked a bystander for directions to a location on a university campus. While the subject gave directions, two people carrying a door would interrupt by walking between the confederate and the subject. Then the confederate would switch places with one of the people carrying the door and the new person would continue the exchange with the subject. Only about 50% of people noticed the change, most of whom were students close in age to the confederate. However, when a follow-up was conducted in which all the confederates dressed as construction workers, students detected the change at roughly the same rate as non-students.

While the study by Simons and Levin (1998) is quite dramatic, most studies of change blindness use laboratory methods rather than field methods. Rensink, O'Regan, and Clark (1997) utilized the flicker paradigm, in which an original image is presented briefly and then replaced with an altered image after an ISI. O'Regan, Deubel, Clark, and Rensink (2000) made changes to

their stimuli contingent on participants' eye blinks. In most cases some form of visual disturbance is required, be it an ISI or physical door, to elicit change blindness (Turatto, Bettella, Umiltà, & Bridgeman 2003). Although these experiments explore how to elicit change blindness, the question remains: what conditions must be met in order for change detection to occur?

In the study by Wilson and Goddard (2011), participants were presented with eight rectangles, one of which had a 50% chance of rotating after an ISI. When no cue was given, participants detected the change at a rate no greater than chance, but when a cue was given during the presentation of the pre-change stimuli, performance was nearly perfect. We believe that the cue may have allowed participants to attend to the aspects of the stimuli which were necessary to detect the change, thereby increasing performance. However, the cue also served a more basic purpose: it directed participants' gaze to the location of the change, enabling them to obtain the visual information which has been assumed to be necessary. While change blindness research has shown that the visual information is not sufficient for change detection, whether it is necessary has not yet been established. Given the physiological limitations of the eye, it seems likely that participants would need to fixate on a change in order to detect it.

The current study examines whether fixation is a prerequisite for change detection.

METHOD

Participants

Thirty-six participants (26 female and 10 male) with a mean age of 20.7 years took part in this study. Participants were recruited either through SONA Systems, which awards extra credit to students in psychology classes, or by word of mouth. Participants recruited by word of mouth received no compensation. This study was approved by the Institutional Review Board of the University of Central Florida (Appendix A).

Stimuli

Participants viewed a series of four pairs of black-and-white line drawings depicting realistic scenes (Appendix B). Eight differences existed between the drawings in two of the pairs and nine differences existed between drawings in the remaining two pairs. In all other aspects the images were identical. When presented to the participants, each difference fit entirely within a circular region covering no more than 2° of the participants' visual field, which is equivalent to the size of the fovea (Foley & Matlin 2010). The differences were intentionally constructed to be this size so that if a participant fixated on the center of a difference, the entire difference would fall within the foveal region.

These stimuli were the same type of images used in "spot the difference" games. Simons and Levin (1998) comment that in such stimuli, the differences are purposefully camouflaged, making the differences difficult to find despite both images being visually accessible simultaneously. We decided to use such stimuli for this reason. The present study seeks to examine how humans use their visual systems to detect changes. A change detection task which proved to be too easy would provide little data, especially if participants were able to find all the

differences almost instantaneously. In addition, having both images available simultaneously, as opposed to consecutively as in the flicker paradigm, would prevent detection failures due to sparse or decaying mental representations. By removing the necessity for participants to rely on their mental representation, we are enabling them to use the stimuli as an “outside memory,” which the environment does during natural viewing (Mitroff, Simons & Levin 2004). Having both images present allows participants to check the original image whenever they need to, refreshing their mental representations.

Apparatus

The stimuli were presented on a single Samsung SyncMaster 204T 20 inch monitor with a resolution of 1600 x 1200 pixels positioned 30 inches away from the participants. The entire display fell within 24 degrees of the fixation point when the participant fixated on the center of the screen. We used this range based on a study conducted by Posner, Snyder, and Davidson (1980) which found that participants could detect a stimulus located 24° away from the fovea. If fixation is not necessary for change detection, then participants should be able to detect changes while maintaining their fixation point near the center of the display.

In order to determine the location of participants’ fixations, we decided to use eye tracking to record participants’ eye movements as they performed the change detection task. While head-mounted eye tracking systems allow participants’ eye movements to be recorded through a range of head movement, they tend to be more time consuming to set up and calibrate for each participant than desktop-mounted eye tracking systems. In addition, because our stimuli were presented on a single, stationary display, there was no need to track participants’ eye movements through a range of head movement.

Our lab possesses a faceLAB 5 eye tracking system. The faceLAB 5 eye tracking system collects data at a rate of 60 Hz and uses dual cameras and an infrared (IR) emitter pod (shown in Figure 2) to track eye rotation up to +/- 45° around the y-axis and +/- 22° around the x-axis. The typical gaze measurement is accurate within 0.5° to 1° of eye rotation. The faceLAB 5 is also capable of tracking head position and rotation, and recording eyelid and lip behavior, though these functions were not necessary for the current study.

Figure 2: faceLAB 5 Eye tracking cameras and infrared pod

The faceLAB 5 eye tracking system is unobtrusive and requires no form of head restraint. However, we chose to use a chin rest to maintain participants' head position throughout the experiment, and prevent them from leaning forward during the change detection task. In addition, the system is able to auto-calibrate to each participant, reducing the amount of time needed to set up for the experimental session. If necessary, the eye tracker can be manually calibrated, a process in which the user defines points of reference on the participant's face which

are used by the faceLAB 5 software to locate and track the eyes. While the system is fairly easy to use, certain participants, including participants wearing glasses or heavy makeup, are difficult for the faceLAB 5 to track.

The faceLAB 5 software includes a 3D world model, which allows the user to build a virtual representation of the environment. The objects and planes constructed in the world model can be resized and moved to match the size and locations of the corresponding objects in the experimental environment. While the eye tracker is in use, the world model can be used for real-time visualization and analysis of participants' gaze location. The data can also be recorded and used in later analyses, and is natively integrated with EyeWorks, a software package for eye tracking research, which is capable of designing experiments and collecting and analyzing eye tracking data.

Procedure

After obtaining consent, the eye trackers was calibrated using a nine point calibration array. Each participant completed four counterbalanced trials of the change detection task. At the beginning of each trial, on-screen instructions were presented to participants, telling them to click on the differences as they were detected. When a difference was clicked on, a red circle encompassing the entire difference appeared, marking which differences had been found. During the trials, an experimenter supervised the participants to prevent random clicking, which would have caused false detections. Participants were also informed of how much time they had to complete the change detection task. Any one participant had either 3 minutes or 1.5 minutes for each trial. The amount of time to complete the change detection task was manipulated in order to

provide additional variation to the data. After completing the trials, participants took a short demographics questionnaire.

Analysis

EyeWorks Analyze, a program which algorithmically analyzes raw eye tracking data, was used to identify fixations. A temporal threshold of 100 ms and a spatial threshold of 5 pixels were used to detect fixations. A threshold of 100 ms has been shown to be able to discriminate fixations from other eye movements (Manor & Gordon 2003). According to Salvucci and Goldberg (2000) fixations are rarely shorter than 100 ms and often have a duration of 200-400 *msec*. When we exported our fixations with a 100 ms threshold, they largely matched this description.

In EyeWorks Analyze, regions of interest with a diameter of 4° of visual angle were used to determine whether participants fixated on the differences (see Figure 3). Any fixation within one of these regions constituted a fixation of the difference. A diameter of 4° was used as opposed to 2° (the size of the fovea) so that fixations with only partial foveal coverage of the difference would be detected. This would allow participants to fixate anywhere within a 2° radius of the change, and their fixation would still be considered a fixation on the difference.

All detected differences were categorized as either Double Fixation, Single Fixation, or Zero Fixation. A detection was considered a Double Fixation if the participant fixated within the corresponding regions for a difference in both images. If a fixation had occurred within a region in only one image, the detection was considered a Single Fixation, and if the change was detected without a fixation in either region, it was considered a Zero Fixation.

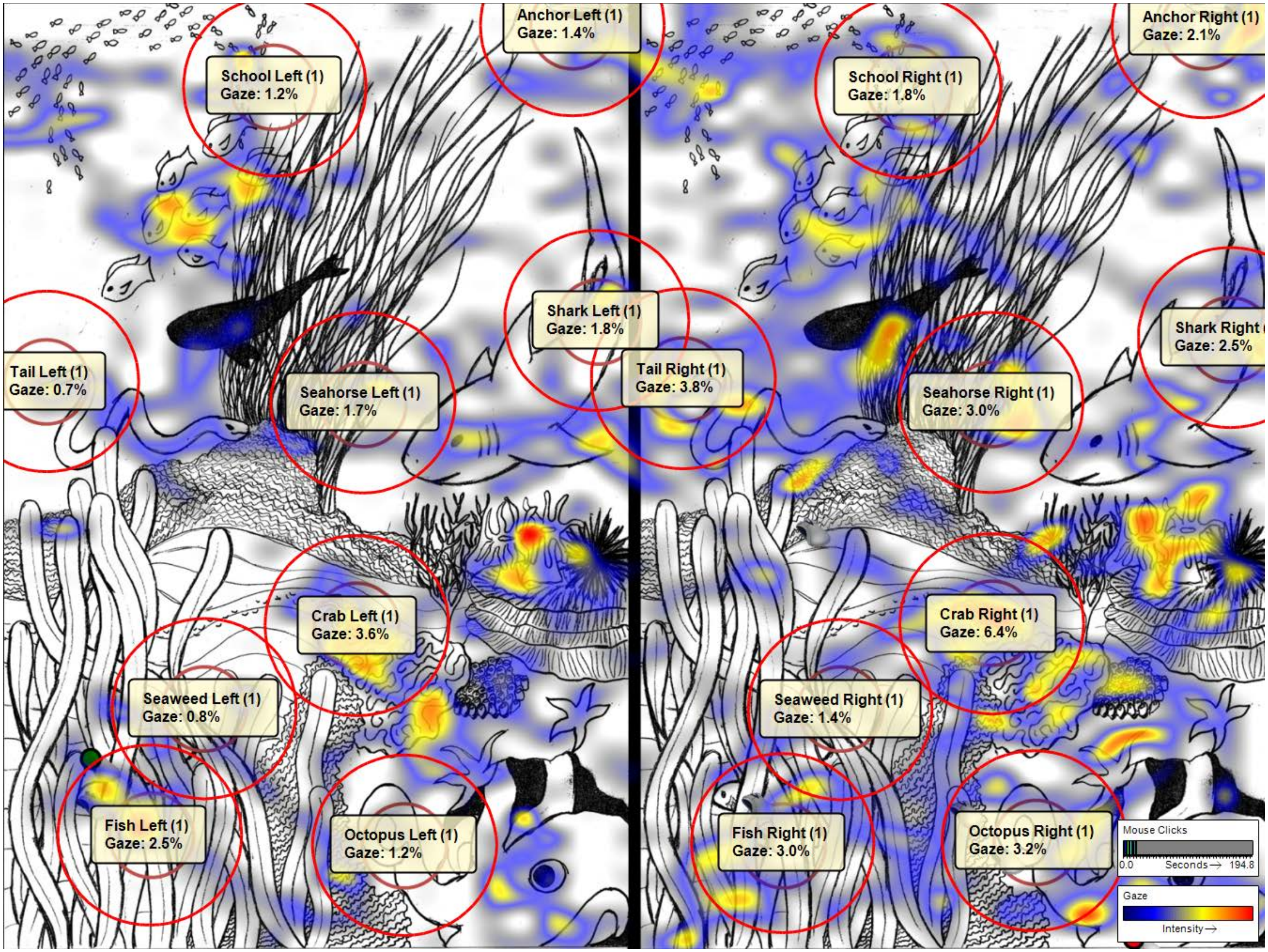

Figure 3: Gaze heat map with regions of interest

RESULTS

Two differences and all corresponding detections were removed from this analysis, because the differences were located in a region where the faceLAB 5 eye tracking system experienced difficulty tracking the participants' gaze.

In the 3 minute condition, participants detected a mean of 22.67 (*SD* = 2.70) differences with a Double Fixation, 1.67 (*SD* = 1.41) differences with a Single Fixation, and .11 (*SD* = .32) differences with a Zero Fixation. In the 1.5 minute condition, participants detected a mean of 17.50 (*SD* = 4.02) differences with a Double Fixation, 2.22 (*SD* = 2.49) differences with a Single Fixation, and .11 (*SD* = .32) differences with a Zero Fixation.

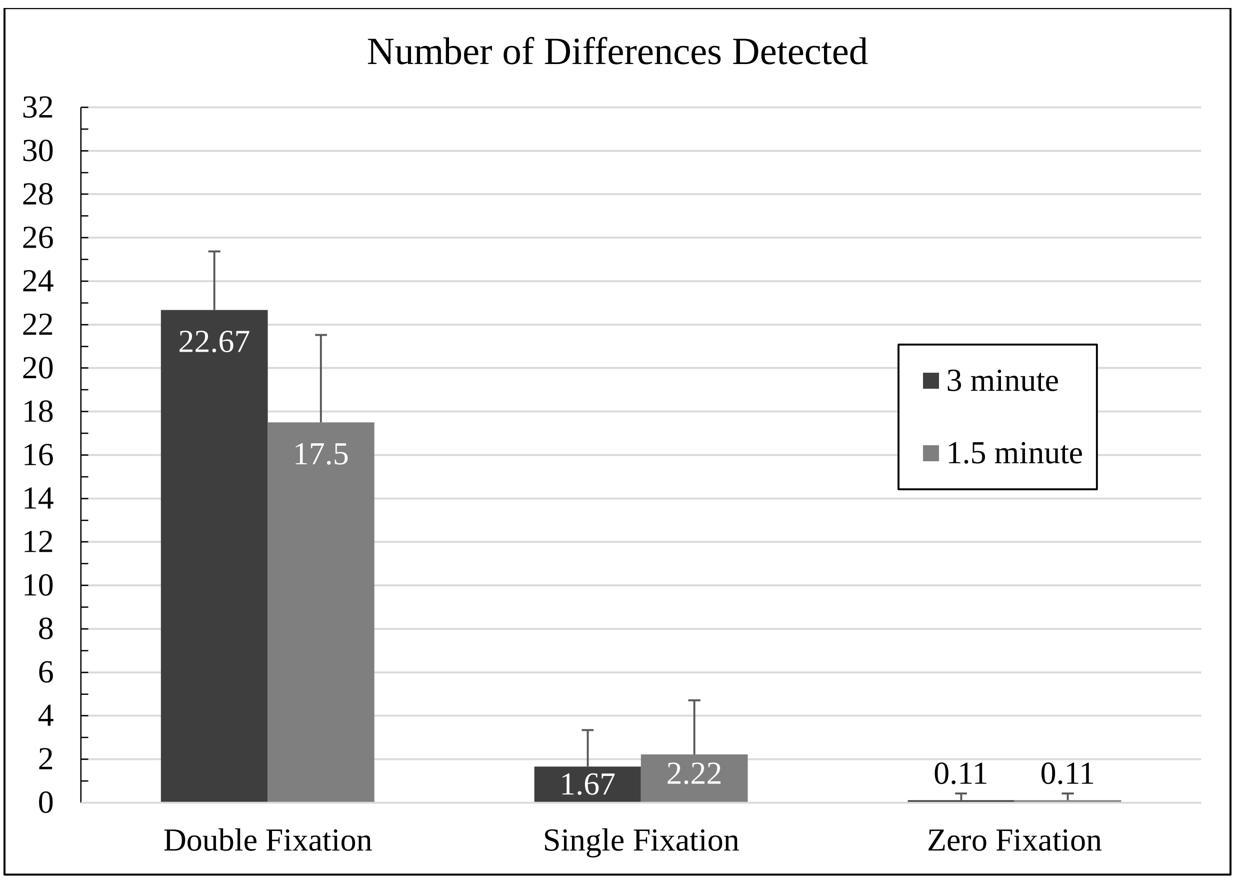

Figure 4: Number of detected differences by fixation type

We conducted three independent samples t-tests to determine if the number of differences detected with a double, single, or zero fixation differed between the 3 minute and 1.5 minute conditions. There was a significant difference between the two conditions for the number of differences detected with a double fixations [t (34) = 4.53, p < .001]. The difference in the number of detections with a single fixations was non-significant [t (34) = .824, p = .41]. The difference in the number of detections made with a zero fixations was also non-significant [t (34) = .00, p = 1.00].

DISCUSSION

It may seem to be common sense that participants find more differences when given more time; however, because this was only true for detections made with a double fixation, we believe our results support the claim that visual information, and often foveal visual information is necessary for change detection. It appears that in the majority of cases participants must fixate on a difference in both the pre-and post- change states in order to detect it. Without this information the two states cannot be compared, which leads to change blindness.

We further contend that the differences detected in either single or zero fixations are likely due to an expected margin of mechanical error. In other words, the participant likely fixated on the difference in both images, but the eye trackers failed to record the eye movements appropriately. However, it may be that certain differences are detectable without direct fixation. For instance, a difference in which a dark object appears or disappears may not require foveal vision for participants to detect it. This would enable participants to detect such a difference with parafoveal or even peripheral vision. Because the number of differences detected with a single or zero fixation were not significantly different between the two time conditions, we believe that these detections might be due to error, as stated above, but it is also possible that our stimuli contain a limited number of differences which are detectable with non-foveal vision. In addition, the relatively small number of detections made with a single or zero fixation could support either explanation at this point.

In the current study, we have only conducted a very basic analysis of the data. A future analysis will be conducted to determine whether participants fixated on differences which remained undetected. It may be that, similar to O’Regan, Deubel, Clark, and Rensink (2000), our

participants failed to detect differences even after directly fixating on them. Additionally, we plan on categorizing differences as either appearances/disappearances or shifts in position to analyze whether these two types of differences were detected in different ways. We believe this analysis help determine whether detections made with a single or zero fixation are true detections or are due to error. O'Regan, Deubel, Clark, and Rensink planned on conducting this comparison; however, due to a large amount of their data being omitted from their analysis, this comparison was never made.

For our current analysis, we measured performance as the total number of differences detected at the end of the given time. While this allows for a simple analysis, it fails to fully describe how participants detected differences. For example, if males found every difference within the first 10 seconds and females found every difference in the last 10 seconds, our current analysis would detect no difference between the two groups, even though a difference clearly does exist. Therefore, we plan on examining performance in other ways to determine if such differences exist within our data.

In addition, we plan on examining individual differences in participants' scanning patterns. We believe that participants who found most of the differences may have different scanning patterns than those who found relatively few changes. One particular element of scanning we plan to examine is checking behavior. This is when a participant fixates on the location of a difference multiple times in succession before report the difference. Mitroff, Simons, and Levin (2004) note that observers tend to be conservative when reporting changes. However, a behavior such as checking would seem to be detrimental to this task, since time spent re-fixating on a location cannot be used to scan previously un-scanned locations.

In the introduction we mentioned that a cue might allow participants to focus all their attention on the cued stimulus, enabling them to ignore all other stimuli present. Future research should examine whether this is true and if “erroneous” details are completely or only partially ignored. Finally, future research should identify and examine situations when a fixation may not be necessary to detect a change. For instance, dramatic color changes may be detectable in the periphery such as when an object changes from blue to red or vice versa. Also, very large changes may be detectable without a direct fixation.

Change blindness research has contributed greatly to the understanding of visual processing, especially in regard to how much people fail to notice even with their eye wide open. However, in addition to examining in what ways people are blind, research should also study how people see.

APENDIX A: IRB APPROVAL LETTER

University of Central Florida

University of Central Florida Institutional Review Board
Office of Research & Commercialization
12201 Research Parkway, Suite 501
Orlando, Florida 32826-3246
Telephone: 407-823-2901 or 407-882-2276
www.research.ucf.edu/compliance/irb.html

Approval of Human Research

From: **UCF Institutional Review Board #1**
FWA00000351, IRB00001138

To: **Benjamin Sawyer** and Co-PI: **Elisabeth A. Niederman**

Date: **March 07, 2013**

Dear Researcher:

On 3/7/2013, the IRB approved the following human participant research until 3/6/2014 inclusive:

Type of Review:	UCF Initial Review Submission Form
Project Title:	Investigation of Visual Acuity on Change Detection and Change Blindness
Investigator:	Benjamin Sawyer
IRB Number:	SBE-13-09201
Funding Agency:	
Grant Title:	
Research ID:	na

The scientific merit of the research was considered during the IRB review. The Continuing Review Application must be submitted 30days prior to the expiration date for studies that were previously expedited, and 60 days prior to the expiration date for research that was previously reviewed at a convened meeting. Do not make changes to the study (i.e., protocol, methodology, consent form, personnel, site, etc.) before obtaining IRB approval. A Modification Form **cannot** be used to extend the approval period of a study. All forms may be completed and submitted online at https://iris.research.ucf.edu .

If continuing review approval is not granted before the expiration date of 3/6/2014, approval of this research expires on that date. When you have completed your research, please submit a Study Closure request in iRIS so that IRB records will be accurate.

Use of the approved, stamped consent document(s) is required. The new form supersedes all previous versions, which are now invalid for further use. Only approved investigators (or other approved key study personnel) may solicit consent for research participation. Participants or their representatives must receive a copy of the consent form(s).

In the conduct of this research, you are responsible to follow the requirements of the Investigator Manual.

On behalf of Sophia Dziegielewski, Ph.D., L.C.S.W., UCF IRB Chair, this letter is signed by:

Signature applied by Joanne Muratori on 03/07/2013 02:42:22 PM EST

Joanne Muratori

IRB Coordinator

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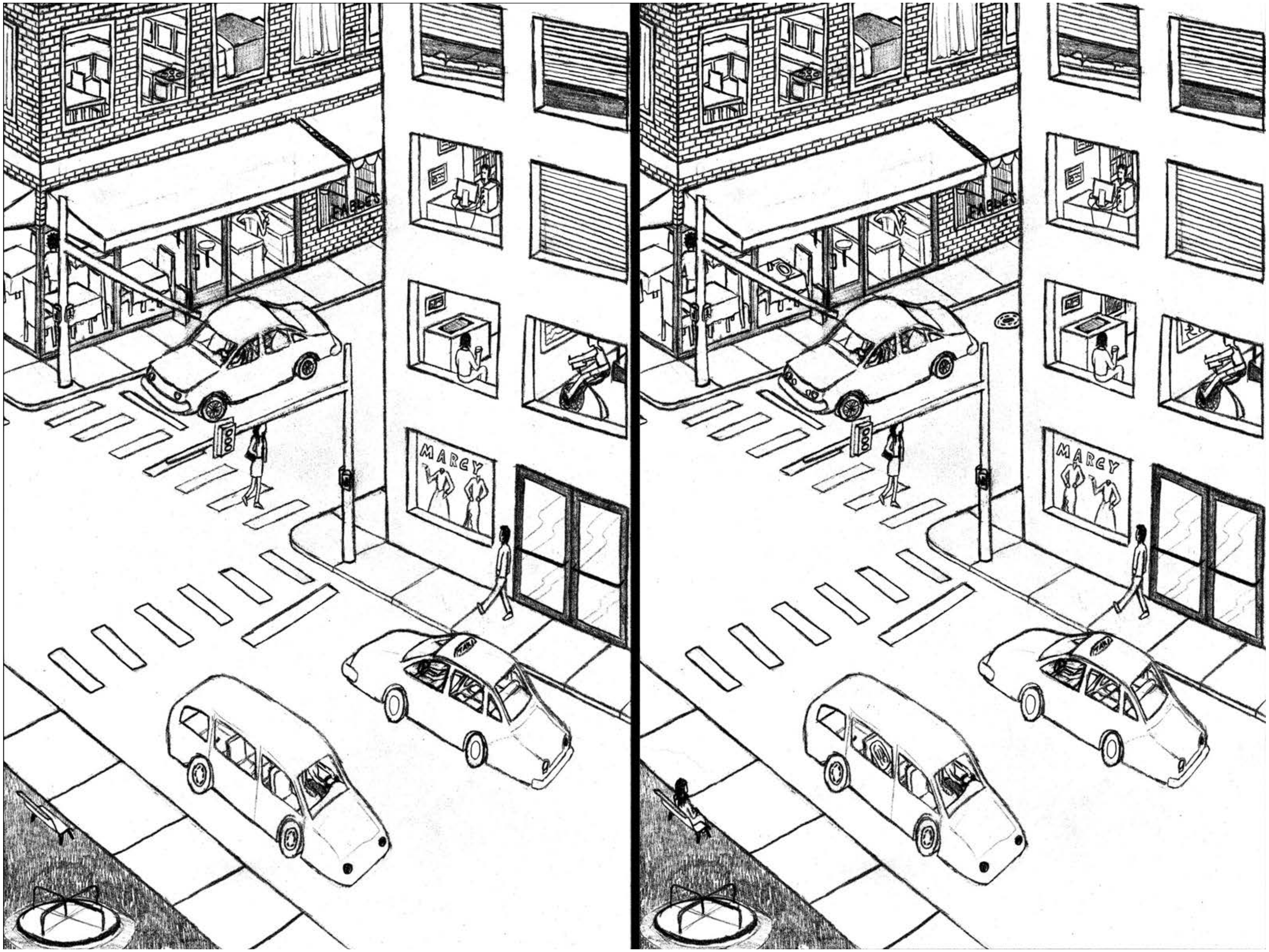
APENDIX B: STIMULI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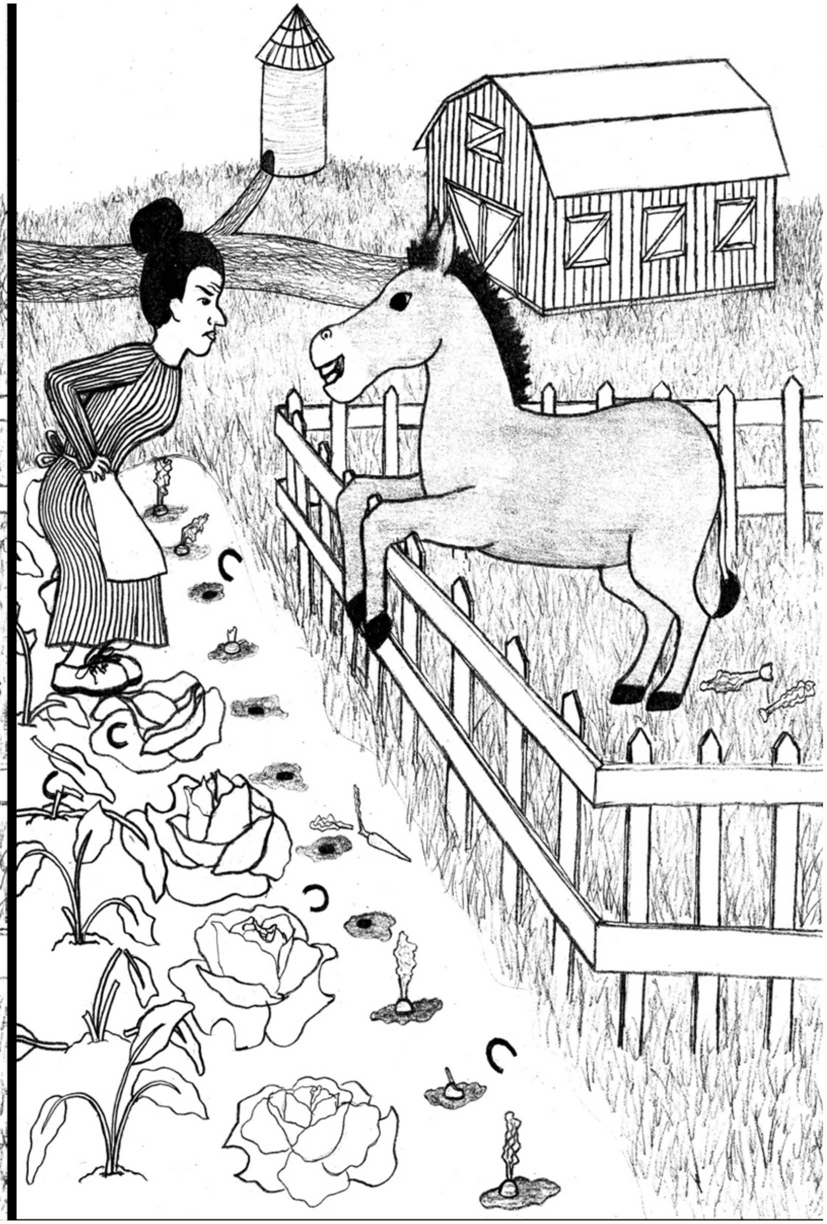


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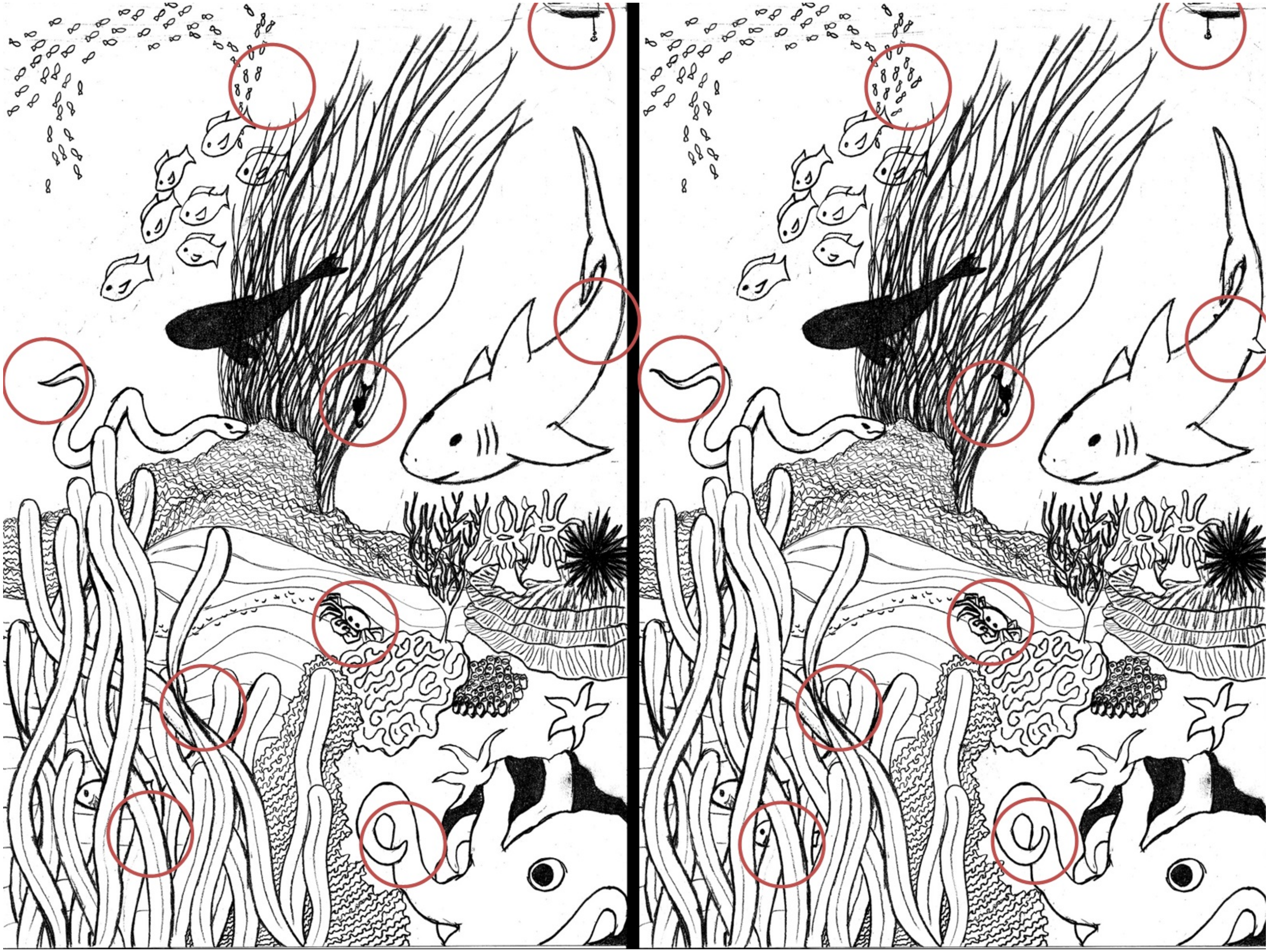

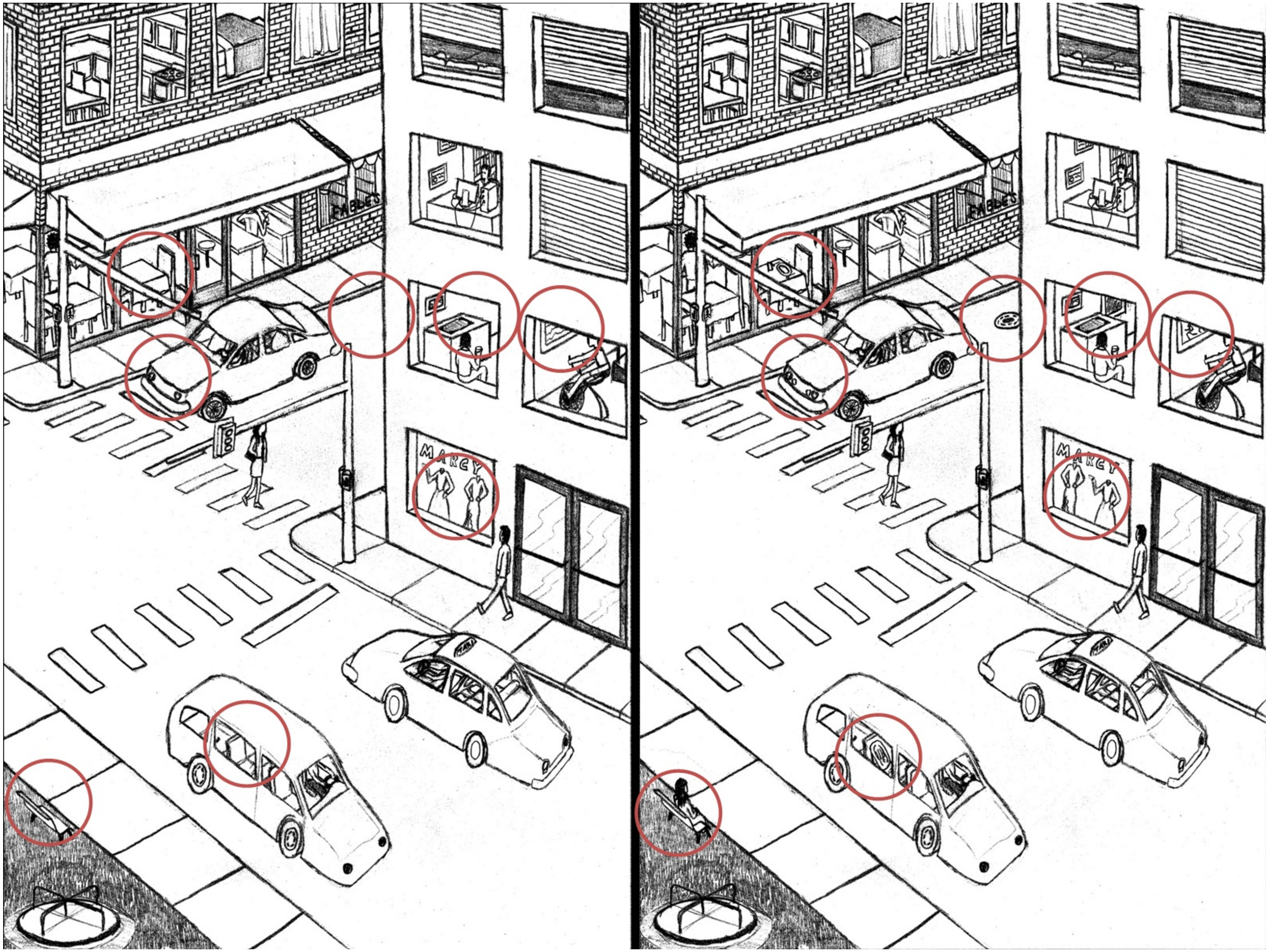
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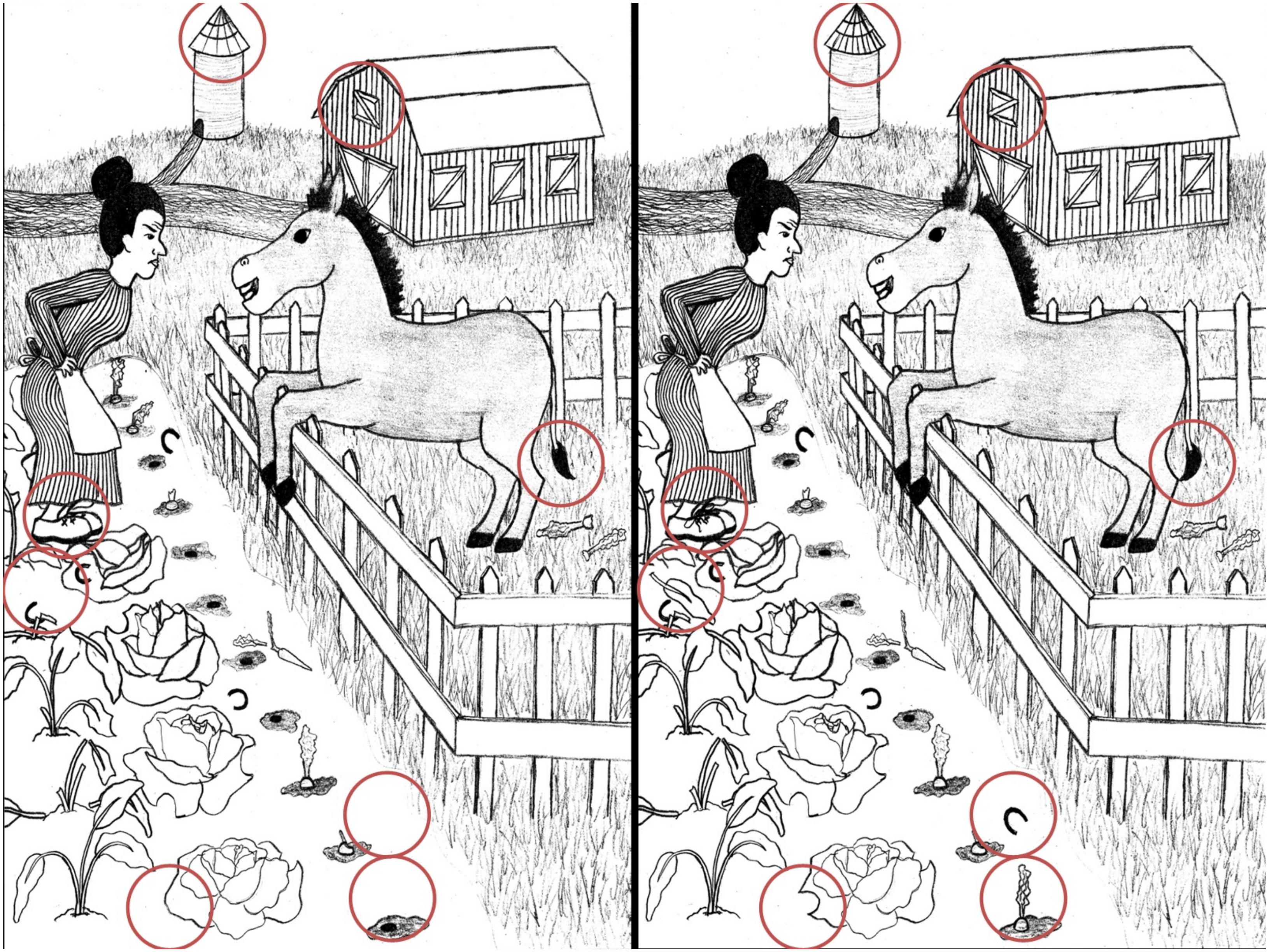

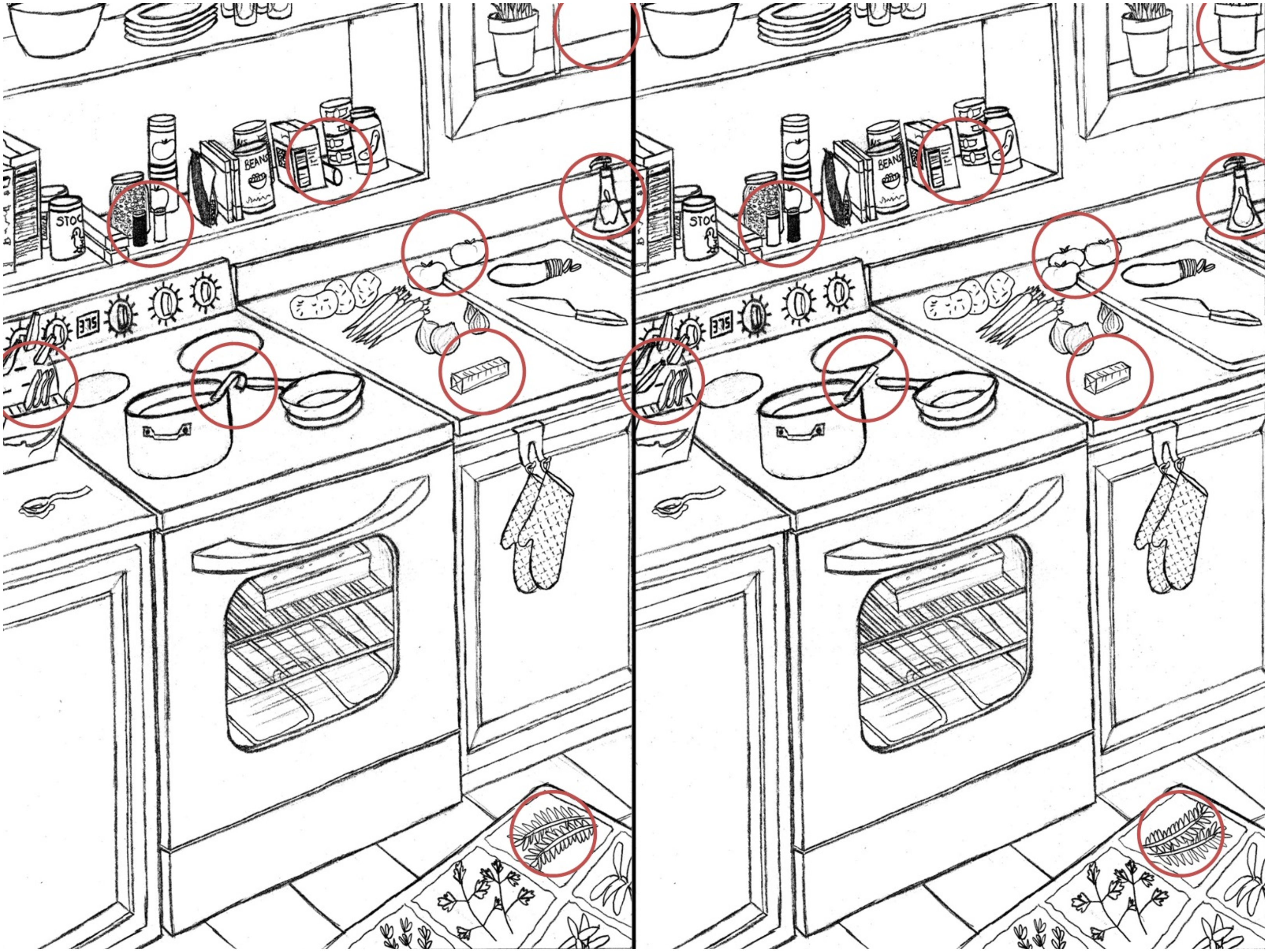
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