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WHO IS THIS DESIGN FOR? PROMOTING CONSIDERATION OF PEOPLE DURING CONCEPT GENERATION

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ABSTRACT

The success of a design is not determined solely by its technical aspects. A design must work for the people who will be using it and in the context in which it will be used. Human-centered design approaches suggest strategies to remind engineering designers of the people impacted by their design decisions. While many of these strategies can be used within and across multiple design phases, during the act of sketching concepts during concept generation, there are few explicit strategies for centering people. We investigate possible impact from a simple intervention during a concept generation task through a between-subjects experiment. Working alone is a single design session, half of a group of mechanical engineering students were asked to explicitly "represent people" within their conceptual sketches. Afterwards, all students reviewed each of their concepts to answer, "Who is this idea for? Who do you imagine would use it?" Those who received the intervention requiring representation of people within concept sketches produced significantly longer reflections with greater depth compared to the control group. Adding drawings of people to sketches resulted in more consideration of the social and physical context of use and of the user's personal preferences and values. Depicting people in generated concepts substantially reduced claims a design is "for everyone," suggesting explicit representation of potential users produced more thoughtful consideration of diversity among potential users.

Keywords: user-centered design; design visualization; design process; design theory and methodology; design representation; product development

1. INTRODUCTION

Engineering designs may leave a gap between technical design quality and meeting the needs of the people who use them. Many design approaches emphasize attention to people, including human-centered design [1], user-centered design [2], and inclusive design [3], and design thinking [4]. While these approaches differ, all emphasize the need to "center" the people who will be using and interacting with completed designs to create contextually appropriate solutions. There are various strategies that designers can leverage to consider people within and across various design phases. For example, in early design stages, engineers can conduct research on end use context [5] and interview a variety of potential users [6]. During problem exploration or requirements development, engineers can use a variety of low-fidelity prototypes in their interactions with stakeholders to support a deep understanding of needs [7]. During later-stage design activities like design embodiment, engineers can conduct usability testing with people to understand product functionality and user experience [8].

During concept generation, one way engineers center people is through co-design, the process of including users as design partners when generating solution ideas [9]. More often, however, potential users are not present on design teams, leaving engineers to create and maintain their own consideration of potential users. Explicit strategies could benefit designers as they sketch concepts to help them center people. Thus, in a laboratory experiment, we investigated a novel strategy to aid engineering designers in considering people during concept generation. Advanced undergraduate students in mechanical engineering worked alone to generate concepts for a design problem. A control group generated concepts naturally and an intervention group were asked to explicitly "represent a person" in their concept sketches. Later, all described (for each concept separately) who their design was for and who they imagined would use it. Their responses were analyzed to determine the impact of explicit representations of people in concept sketches on consideration of people during design.

2. RELATED WORK

2.1 Centering people in engineering design

There are a variety of design approaches that have been developed to close the gap between people's needs and design outcomes: inclusive design, human-centered design, design justice, participatory design, and ability-based design, to name a few. Each approach has developed in distinct disciplines and therefore offers different values, perspectives, and practices, but all of the frameworks seek to understand people's needs and their contexts holistically [10]. Inclusive design emphasizes understanding who is included and excluded by design decisions [3], [11]; human-centered design prioritizes engaging with a variety of stakeholders in early-stage design activities [1], [2], [10]; design justice seeks to empower marginalized communities to lead design decisions, thereby destabilizing and challenging structural inequity [12]; participatory design shifts from designing *for* users to designing *with* users, establishing partnerships between designers and the intended contexts of use [13], [14]; ability-based design shifts the focus from users' disabilities to designing for users' varying abilities [15].

These people-centered design approaches encourage engineers to more meaningfully consider the people who will impact or be impacted by design decisions. The "people" are often known as stakeholders [16], but perhaps the most obvious and relevant stakeholder is the primary end user of the product or system being designed. User engagement is a crucial endeavor of design work. During front-end design, user engagement can impact problem understanding, requirements development, and concept generation [17] [18]. There are many ways engineers engage with users during early stages of design. For example, during concept generation, engineers might invite users to jointly develop potential solutions in a process called co-design [9]. To develop problem understanding, engineers might interview a variety of stakeholders [19]. Costanza-Chock [20] described how the level of user engagement or community participation may vary between various phases of design depending on the design project.

There are times in design when it is not possible to engage directly with users, but it is still important to keep potential users in mind and center their needs. One example of centering people while developing problem understanding is performing background research on user context [21]. Designers might leverage "body-storming," a practice where the designer physically acts out the tasks or role that a user might experience [22], [23]. Personas or persona spectrums, which are visual profiles of potential users based on aggregated data, are recommended for supporting centering people during a variety of design activities, including problem definition, requirements development, concept development and evaluation [3], [24]. Similarly, storyboards, which are comic-strip-like illustrations of a potential user experience [25] and virtually rendered user representations as are leveraged in human-computer interaction [26] can support people-centeredness during the definition and evaluation phases of design work. While mental visualization during concept generation has been shown to lead to designs more appealing to the customer [27], it is less clear if personas or other visual representations support deeper consideration of people during concept generation.

Centering people means considering a variety of dimensions of people. Along with ergonomic considerations of physical and cognitive variation [28], aspects of people's social identity may need consideration during design [29]. Aspects of people's social identity include: gender, alignment with gender assigned at birth, sex, race, ethnicity, sexual orientation, religion or spirituality, social class, age or generation, ability or disability, nation of origin or citizenship, tribal or indigenous affiliation, and body size or type [30], [31]. Many disability justice scholars understand people as 'body-mind-spirits,' analyzing each part independently as well as their interactions [32], [33]. People can also be understood as part of their communities: guided by disabled Black and brown queer communities, Piepzna-Samarasinha described people as part of interdependent 'care webs' giving and receiving what is needed to uphold each other with autonomy and dignity [34].

2.2 Role of empathy in engineering design

Meaningfully centering users in design requires deep empathy for those users. Empathy allows engineers to more fully understand their intended users in order to inform engineering decisions [35], [36]. When considering users, it is crucial that engineers holistically and honestly consider the people impacted by their decisions [37]. By practicing empathy, engineers can align engineering decisions with the values and feelings of the people for whom they are designing. Bennett and Rosner described empathy as an ongoing process, yet one that can be 'slippery,' indicating that not all attempts at fostering empathy are successful, and can in fact be harmful [38]. Kujala and colleagues similarly emphasized the 'dark side' of user engagement, which can cause various negative impacts on stakeholders [39]. As examples, one study asked engineers to build empathy for potential users through use-case simulation exercises, such as attempting to use a product with thick gloves to simulate actual disabilities like arthritis, finding positive effects on concept generation outcomes [40]. Another study prompted designers through simulated experiences with visual impairments, finding positive effects on both creativity and empathy [41]. However, many sources across disciplines criticize the morality and holistic effectiveness of disability simulations and role-playing [38], [42]–[44]. Therefore, it is essential that engineers approach future attempts at building empathy with care.

Empathy plays a critical role in engineering, yet it can be difficult for engineers to foster it, in part due to its limited or unclear emphasis in engineering education and practice [45]. Studies on engineering students building empathy vary. An attempt to induce gratitude in students to promote more creative designs and greater empathy led to inconsistent results across experimental tasks [46]. One study found that student engineers leverage empathy in team settings, problem contextualization, human-centered design, and for individual inspiration [47].

Another study found the engineering students' empathy did not increase over the course of an 8-week design project, perhaps due to a lack of access to potential end users, even though the students identified empathy as important [48]. Further analysis of the same study identified that students' intrinsic empathic concern correlated with students generating more potential concepts, but did not impact the creativity of concepts generated [49]. The variation across empathy studies further underlines the complicated nature of empathy.

2.3 Building on concept generation strategies

One opportunity to build on existing engineering design tools, improve empathy-building, and increase user consideration is concept generation. Concept generation is a front-end design activity that can have a large impact on the creativity and innovation of later stage design outcomes [50]–[52] through a process of identifying a diverse set of potential solutions to a problem [53], [54]. Many existing strategies support successful concept generation, including Brainstorming principles [54], TRIZ principles to support innovation in product design [55], and Design Heuristics including 77 empirically identified strategies to support a more creative and diverse set of concepts [56]. While effective for generating more and varied concepts [57], [58], there is less guidance offered about centering people during concept generation. Some Design Heuristics strategies reference consideration of people, such as "Adjust functions for specific user" and "Allow user to customize." However, in a team design project study, Rao and colleagues [59] observed a shift during concept generation away from user-focused outcomes to product-focused outcomes. This suggests investigations of strategies to promote considering people during concept generation is needed. When co-design approaches and exploration methods are not possible, how can engineers be supported in centering people during the key design activity of concept generation?

3. METHODS

The following research questions guided our study:

1) Who do students design for during concept generation?

2) How does including people in sketches impact who designers imagine as users of their designs?

3.1 Participants

We recruited 40 mechanical engineering undergraduates enrolled in a large Midwest American R1 university. Participants were recruited through a mechanical engineering majors email list. All participants were mechanical engineering majors in their 2nd, 3rd, or 4th year of study and had completed a core project-based engineering design course. Participants self-identified their race and/or ethnicity as Asian (20), white (10), multi-racial (9), and Hispanic/Latinx (1), and their gender as man (26), woman (13), and non-binary (1). The protocol was reviewed and approved by a university IRB. Each student received $30 as compensation for one hour of participation.

3.2 Data Collection

Four one-hour sessions were held to collect data. Participants in two of the four sessions (n=20) were assigned at random to receive the intervention with instructions to represent people in their concept sketches. In all sessions, we asked participants to generate as many solutions as possible for a presented design problem, which is shown in **Figure 1**, while working independently for 30 minutes. Participants recorded each concept on a separate sheet with a space to draw and a space to describe the concept in detail.

Design Problem: Helping People Move
Moving is considered one of the top stressors in life. When people move, they experience multiple challenges. For example:

- lifting heavy furniture
- navigating through small spaces (door frames, corners, narrow hallways, stairs)
- keeping belongings organized
- finding other people to help them move
- continuing living (and even working) while belongings are in transit
- moving in extreme weather (snow, heat, rain)
- and many others...

Imagine you are asked to design for this problem. Considering one or more challenges on moving day, design a way to help people move households. Make sure to consider the physical setting in your solution.

FIGURE 1: DESIGN PROBLEM PROVIDED TO PARTICIPANTS

Participants in the two sessions receiving the intervention were also told to "include representations of people, a person, or parts of a person" within their concept sketches. The intervention participants were also provided with three example sketches that represented people in some way, which are shown in **Figure 2**.

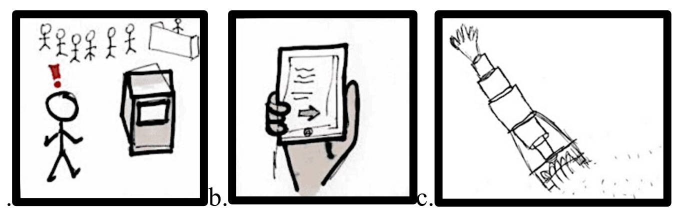


FIGURE 2: SKETCHES PROVIDED AS EXAMPLES WITH INSTRUCTIONS TO INCLUDE REPRESENTATIONS OF PEOPLE (IMAGES A AND B SOURCED WITH PERMISSION FROM TRUCCHIA [60]).

After the concept generation session ended, participants were asked to return to each concept and respond to the questions: "Who is this idea for? Who do you imagine would use it?" Participants worked at their own pace for up to 15 minutes to complete their written responses to the questions for all their concepts. Two example concepts from different participants are shown in **Figure 3**.

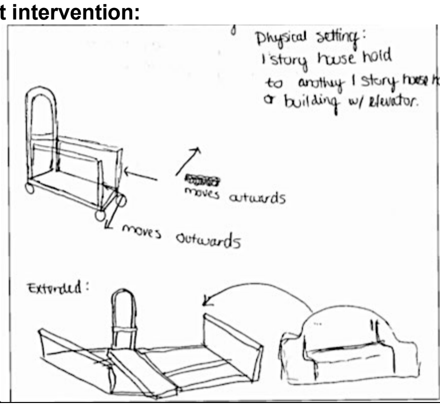
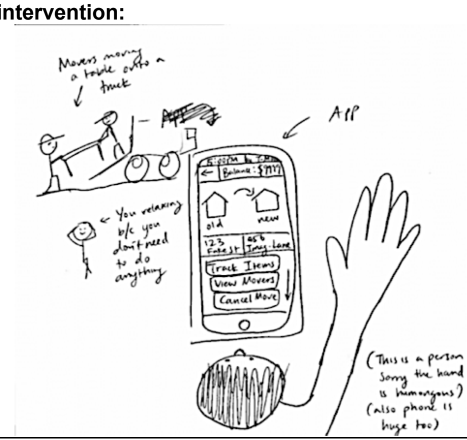
<table>
<tr><td>Example Participant Concepts</td><td></td></tr>
<tr><td rowspan="2">Sketch without intervention:

</td><td>Written Concept Description: The mechanical trolley serves the same purpose as a traditional trolley, what makes this trolley “mechanical” is that it has two side panels that can extend outwards. The panels serve as a support to hold whatever object in place. (Objects could be furniture, appliances, etc.). The extra support allows bigger objects to be moved more securely without the help of other people.
Labels: Physical setting: 1 story household to another 1 story household or a building w/ elevator; moves outwards; moves outwards; extended.</td></tr>
<tr><td>Written Question Response: This idea is for people who possess more upper body strength than the average person. The trolley has the panels for extra support, but in order to transport the heavy object, upper body strength is needed. I can imagine people who are moderately physically active to use this tool.</td></tr>
<tr><td rowspan="2">Sketch with intervention:

</td><td>Written Concept Description:
-Moving is (hopefully) something people don't do often, and finding friends to help you move especially in a new (illegible) is difficult - This is an app you can use to hire movers on demand (like doordash, instacart, etc.) -The app can track your belongings and other cool stuff
Labels: Movers moving a table onto a truck; App; You are relaxing b/c you don’t need to do anything; (This is a person sorry the hand is humongous); (also phone is huge too)</td></tr>
<tr><td>Written Question Response: This idea is for people who: are moving to a new city; can’t be very involved in moving process; don't have friends who can help move; have trouble lifting heavy furniture; don't want to bother/ask friends to help move. People who would use this: young adults, college students, adults, older folks, anyone 18+</td></tr>
</table>

FIGURE 3: TWO EXAMPLE CONCEPTS WITH SKETCH, WRITTEN DESCRIPTIONS, AND RESPONSES TO USER QUESTIONS

3.3 Data Analysis

The qualitative analysis focused on participants' written responses to the questions, “Who is this idea for?" and "Who do you imagine would use it?” Two authors first examined all responses in a randomized order. Then, the responses for each concept were coded into categories based on similarities in the user descriptions. The categories were generated separately by the two raters and then compared and discussed to consensus, following recommended practices of thematic analysis [61], [62]. For example, one response noted that, "This could be used by movers and everyday people. This idea is for people who live in areas with extreme weather (or just for people who chose a bad day to move).” This response was coded as referring to *people who are movers*, *people who are everyday people, people experiencing extreme weather*.

4. RESULTS

The 40 participants independently generated 185 concepts in a 30-minute concept generation task, with an average of 4.6 (SD = 1.7) concepts and a range from 2 to 9 concepts. The intervention group generated fewer concepts than the control group, although the difference was not significant, $t(38) = 0.8$, $p > .05$, as shown in **Table 1**. The intervention group successfully generated over 60% more sketches with people depicted, $t(38) = -5.6$, $p < .01$. Only 28% of control concepts included representations of people. These findings suggest the generation task was performed similarly by the two groups, and that students given the intervention understood and followed the instructions to provide representations of people in their concepts. Concept sketches in the two groups appeared visually similar in sketch quality.

TABLE 1: CONCEPTS GENERATED BY GROUP

Study Group	Control	Intervention
Number of Participants	20	20
Number of Concepts Generated	97	88
Number of Concepts with People	27 (28%)	80 (91%)
Average Concepts per Participant	4.9 (SD = 1.8)	4.4 (SD = 1.7)
Maximum Concepts per Participant	9	9
Minimum Concepts per Participant	2	2

Participants' written responses to the two reflection questions ranged from a single word (“Everyone”, C1), to 90 words in length, with an average of 33.8 (17.2) words. Without the intervention, participants generated an average of 2.2 different descriptors (SD = 1.0; range 1 to 5) per concept and the intervention group averaged 3.0 (SD = 1.6; range from 1 to 9). This difference was significant, $t(183) = -3.8$, $p < .01$. The average length of participant concept reflections was also significantly longer in the intervention group, $t(183) = 3.67$, $p < .001$, as shown in **Table 2.** These findings show that using the intervention changed students’ thinking about people in their designs to include more variation, specificity, and elaboration of potential users.

TABLE 2: RESPONSE WORD COUNTS BY GROUP

Group	Number of Written Responses	Minimum Words per Response	Maximum Words per Response	Average Words per Response
Control	97	1	76	29.5 (SD = 14.0)
Intervention	88	9	90	38.5 (SD = 19.1)

Responses to the questions "Who is this idea for? Who do you imagine would use it?" were scored with no category observed in more than 34% of responses. This suggests engineers found describing potential users of their designs challenging, or that individuals thought differently about potential users. The 13 categories of people descriptors identified in the analysis are described with examples in **Table 3.**

Three categories showed significant differences in between-groups Chi-Square tests (df=1) (**Table 4**). Specifically, representing people in sketches increased consideration of people's personal preferences, produced more attention to users' physical environments, and decreased claims that designs are intended "for all people." The intervention group also made more references to users' social community, though this difference was marginally significant. While demographic, identity, and cultural differences among people have been noted as important in design [29], we did not observe any explorations of potential users through specification of citizenship, race, gender identity, sexual orientation, religion, culture, or marital, parental, or partner status.

TABLE 3: DESCRIPTORS OF PEOPLE IDENTIFIED IN PARTICIPANT RESPONSES TO "WHO IS THIS IDEA FOR? WHO DO YOU IMAGINE WOULD USE IT?"

Descriptors of People	Example Quote from Control Group	Example Quote from Intervention Group
People with specific preferences and values	"This is for people who know they will be moving soon and **don't want to hang everything up just to have to take it down**." (C12)	"People who...***are minimalists***." (I1)
People with or without supportive social community	"This idea is for ***people who are bad friends/are such good friends*** that everyone will get a kick out of the …" (C18)	"Someone very disorganized who is going through all their stuff and has ***none to minimal assistance*** packing could use this." (I7)
People who are a particular age	"So most likely ***elderly, young, & those who aren't strong*** enough to move heavy stuff ..." (C6)	"I can imagine a ***young able adult*** using this, since it still requires quite a bit of human movement." (I7)
People who have (or lack) financial resources	"People who want to have a really hassle free move and are ***willing to spend a little more $$ to ease the process***." (C1)	"People ***who have the money*** and need to transport between places where they have to live for a while." (I15)
People with non-monetary skills and resources	"Smart + **social media savvy folk** (age 20-70) likely anyone with a phone can use." (C1)	"I imagine someone who ***just bought a car a***n***d*** is planning to use the car and move around a lot would buy this." (I13)
People who own particular possessions	"People ***with bigger furniture/buying furniture***." (C4)	"This idea is for someone moving that ***has a lot of fragile items*** and doesn't want to individually wrap them." (I12)
People with physical environment constraints	"This idea is for people who ***live on the lower floors*** of apt buildings with no elevators." (C18)	"This idea is for people who are moving ***during extreme weather."*** (I13)
People with particular physical ability	***"Weaker people*** too." (C20)	"Who is this for: ages 12+; especially for individuals ***with physical injuries and/or disability***." (I14)
People who are (dis)organized	***"Disorganized people***? ... Not the most space efficient method but need something to have that ***small little organization aspect."*** **(C4)**	"This idea is for both (moving?) companies as well as a ***well organized amateur.*** I imagine moving companies would use this to ***keep track of inventory...."*** (I18)
People who consider scheduling and stress	"I imagine this is for ***very busy people*** who have the means to use these (services?) while continuing to work or take a vacation to avoid the stresses of (moving?)." (C19)	"All movers, allows automation to help move as many objects to new house as ***quickly and effortlessly*** as possible." (I20)
People who have particular occupations	"I imagine ***businessmen*** using this product." (C7)	"People who has the money and need to transport between places where they have to live for a while. Maybe due to ***occupations."*** (I15)
People who are not the primary user	"Also ***moving companies*** could purchase this to make life easy for their customers." (C8)	"Since it is large and hard to store I would imagine ***professional movers/companies*** would use it the most." (I13)
"All people"	"This idea is for ***anyone*** that is moving." (C21)	"...allows ***all people*** to move their essential furniture most efficiently." (I20)

TABLE 4: FREQUENCY OF SPECIFIC PEOPLE DESCRIPTIONS BY GROUP

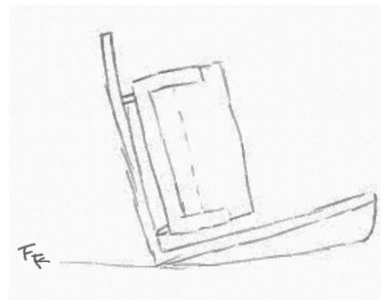
Descriptor Category	Control (%)	Intervention (%)	Difference (%)	Chi Square (df = 1)
Preferences and values	3.09	22.73	19.63	**16.339****
Social community	11.34	20.45	9.11	*2.899^*
Age	12.37	19.32	6.95	1.684
Financial resources	10.31	13.64	3.33	0.487
Non-monetary skills and resources	7.22	10.23	3.01	0.529
Possessions	34.02	27.27	-6.75	0.986
Physical environment	24.74	36.36	11.62	**2.952***
Physical ability	23.71	25.00	1.29	0.041
Organization	13.40	11.36	-2.04	0.176
Scheduling and stress	19.59	21.59	2.00	0.113
Occupations	12.37	5.68	-6.69	2.471
Beyond primary user	11.34	19.32	7.98	2.286
"All people"	22.68	10.23	-12.45	**5.129***
Responses	n = 97	n = 88		

Note: ^p < 0.10; *p < 0.05; **p < .01

These findings show that requiring representations of people in sketches during concept generation increased designers' attention to differences among potential users. Control group participants were more likely to say their concept would work for "all people," even though some sketches and descriptions included more specific user requirements that not all fit. For example, the sketch shown in **Table 5** from a control group participant shows a device to load and tip heavy furniture, presumably requiring particular physical strength and mobility; however, the participant describes that the concept works "for anyone." This pattern indicates that students were not attending to relevant differences among people while claiming their concept works for all.

In addition to the question responses, many specifications of people appeared in concept sketches and descriptions. For example, "Helping with lifting heavy objects with no good handholds," "Can take/store photos especially for people renting to make sure they have them in case anything happens," and, "To find people to help you move, use an app (move-me) to choose movers in your area so you can find affordable help." These examples from sketch descriptions demonstrate thinking about specific qualities or groups of people during concept generation *before* the reflection questions were presented.

TABLE 5: A CONCEPT CLAIMED TO WORK FOR ANYONE IGNORES POTENTIAL PHYSICAL REQUIREMENTS FOR USERS

Concept Sketch and Description	"Who is this concept for?"
 "This concept is to help turn heavy furniture on its side as to get through narrow areas. One would load the furniture on one side, then tip it using a rope or pulley. Maybe also add some wheels on it to be able to use this to move the furniture without having to lift it?"	"This idea is for anyone...I would imagine anyone would use this as it would hopefully make it easier to move furniture in tight places."

5. DISCUSSION

Our findings identified impacts from the intervention on how designers described potential users for their generated concepts. When asked, "Who is this idea for? Who do you imagine would use it?", those asked to represent people in their sketches gave descriptions that differed from the control group in several ways. Although the intervention group produced fewer concepts on average, the intervention did not significantly impact students' productivity. Any slowing may be due to added time for drawing people in sketches, more time spent considering possible users, or some other factor. The intervention group produced longer reflections on who concepts were for, suggesting the intervention promoted intentional, deep thinking about potential users. Previous work also found that visualizing potential users had a positive impact on design outcomes [27].

The design problem asked designers in both groups to consider physical settings, and the problem content (*help people move households)* encourages awareness of physical constraints. With the intervention, consideration of people's physical settings further increased compared to the control group, suggesting depicting people enhanced attention to the users' setting. Other design problems may prompt attention to other considerations about people's experiences and needs; for example, using the intervention when designing a shared electronic may prompt deeper investigations of people's relationships instead of physical environments. Additional work is needed to investigate how intentional representation of people in design concepts increases attention to human experiences.

The intervention prompted more consideration of people's personal preferences and values in creating design solutions. Incorporating user preferences has been suggested as key to successful designs [17], [37]. Zoltowski and colleagues [63] found that some engineering participants understood human-centered design as keeping users' needs in mind through practices such as including stakeholders across design activities, considering design in context, and developing empathy for users. The simple intervention in this study may similarly provide a strategy for keeping the user in mind during the concept generation through their presence in the sketch.

The findings also suggest more consideration of users' social context or surrounding community beyond the end user by the intervention group. People are often embedded in communities sharing resources, time, and care for each other [34], and attention to community beyond an individual user may be aided by depicting people in designs. Other contexts may be important for other design problems. Burleson and colleagues [64] described the importance of incorporating many contextual factors during engineering design, such as the socio-cultural, economic, industrial, and political context of users. Considering all people who impact or could be impacted by engineering designs has been supported in prior work [16], [37], [39].

While participants claimed that their designs worked for "everyone," the intervention halved the frequency of these claims. This suggests the intervention may work to interrupt engineers from generalizing and designing for a single type of user. When engineers imagine a "someone" who will use their new concept, who do they imagine? Hendren [65, p. 12] described designing for 'normalcy' as prolific in engineering and design contexts: "When the average is laden with cultural worth, everything changes: what was common began to be seen as what was 'natural,' and what was 'natural' came to be seen as *right."* In engineering and design education, assumptions of "normalcy" led to designing for the bell curve and thus for the "average" person, who does not exist [65], [66].

One seminal failure from designing for the average occurred in the 1950s with U.S. military aircraft. Engineers measured thousands of pilots, calculating averages for 10 dimensions (e.g., thumb length, torso height). They designed the cockpit to fit those exact average dimensions, only to find that there were *zero* pilots that actually fell into the average range on all 10 dimensions [67]. Most of the Western world is designed for this average user, or "normate inhabitant," which excludes disabled bodies [68]. Those who do not fit the average have been described as 'misfits' by engineered environments not built to include all people [69]. An intentional focus on diverse users and stakeholders can push designers away from the default "average" view. For example, the Design Justice Network [70] describes their approach as, "center[ing] the voices of those who are directly impacted by the outcomes of the design process." This description emphasizes not the average or the norm, but the people *directly impacted,* implicitly requiring a critical evaluation by the designer.

We did not observe a focus from engineers in either group on exploring demographic descriptors such as citizenship, race, gender identity, sexual orientation, relationship status, or religion, perhaps indicating that engineering students need further prompting to encourage consideration of even these obvious variations between people. Some differences in social descriptors appear relevant to the design problem, such as the user's relationship status (partner, children), and prior work has called attention to the need to consider such differences among potential users [29], [30].

Creating a representation of a specific person during design requires choices about their appearance, context of use, and interaction with the design. Future work may investigate how this drawing intervention encourages thinking beyond oneself to other people as intended users. This intervention works to encourage attention to designing for a specific other; however, there are likely many other strategies and methods to promote considering differences in users' needs during the concept generation process. Additional work could also investigate how the intervention interacts with other strategies to center people during design, leveraging the simplicity of drawing people to build on more complex empathy-building strategies.

5.1 Limitations

The experiment employed a single session where mechanical engineering students worked independently to create concepts for a single design problem. As a result, our findings may not extend to other design practitioners, problems, or tasks. While the simple intervention was effective in promoting consideration of people in this study, its impact on design in practice settings or in team design tasks may differ. Due to the need for experimental control, example sketches were provided only to the intervention group to illustrate easy ways (e.g., a stick figure) to depict a person. We could not include sketches for the control group because showing the same sketches may suggest they *should* depict people, and example sketches *not* showing people may also be viewed as instruction. With no sketches as examples, control participants were free to include or exclude representations of people. Some control group concepts (28%) did include stick figures and other depictions of people, and we did not observe differences in sketch quality between groups. Further, the examples in this study were not related in any way to the design task, so fixation on potential solutions in sketch examples is unlikely [71].

Another limitation is that implementing the intervention -- depicting people in concept sketches -- may be especially challenging for engineering designers. Past work has demonstrated training on methods of sketching within engineering curricula have positive impacts on spatial visualization and student confidence [72], [73]. Without such training, the challenge of drawing people may limit how *differences* among people are represented in concept sketches. When participants did note in their reflections that their concepts would not work for people who are physically disabled, their sketches did not appear adequate to communicate this thinking about differences during design. Training and tools for representing people through varied body appearances and abilities may support designers as they think about potential differences among future users of their designs.

5.2 Implications

Strategies that promote thinking about people while designing engineering solutions may aid engineers in expanding perspectives about *who* will use designs. Thinking of *who the design is for* prompts important improvements in human-centered design outcomes based on this study: specifically, that a design is *not* always for "everyone;" and that physical and social contexts may affect design outcomes. Further, when considering specific people (as drawn) rather than generic "people" as the potential user, many relevant differences in people's preferences and values may be more accessible. To illustrate, consider how an engineering designer might benefit from representing people in design concepts while developing crash safety measures for automotive vehicles.

Physical environment: Representing people in concepts for improving crash safety may prompt thinking more about who users are and what environments they are in. When investigating crash prevention, engineers might consider that individuals differ in their abilities to make decisions. For example, Eby and colleagues [48] suggested driver behaviors are affected by unfamiliar areas, night visibility, heavy traffic, and bad weather. The design of weather-actuated warning signs for black ice were found more effective at preventing crashes than conventional signs [74]. Engineers should explicitly seek to understand varying physical environments in the context of use, and representing people during concept generation may facilitate imagining different physical conditions for drivers.

Personal preferences and values: Preferences and values form an important vocabulary to describe differences in people's individual needs. Personal preferences may impact engineering designs through how users choose to use them. For example, some people choose to "seat belt submarine," where the belt shifts down to lay across the soft tissue of the abdomen [75]. When a crash occurs, injuries can be much more severe. Engineers should more deeply consider people's varied preferences and values to assess how they may alter user responses. By designing for people's preferences, engineers may anticipate how their designs may be differently employed by different people, influencing injury outcomes.

Social community: Engineering design may fail in crash safety through not considering broader social impacts. Other people -- and even robots -- interact with drivers' decisions, so vehicles have to be designed not only for the driver but for other drivers as well. At the 2021 Tokyo Paralympics, a visually impaired athlete was hit by an autonomous vehicle and unable to compete [76], and other unanticipated circumstances such as pedestrians outside of the designated crosswalks have resulted in crashes [77]. Further, there are concerns about autonomous vehicle designs failing to recognize people with dark skin or using scooters or wheelchairs [78]. Designers need to consider how people *outside* of the design may interact with and be affected by decisions. Engineers may have many internal and external stakeholders to consider [79], such as managers of production timelines, engineers on other vehicle systems, and priorities and goals of a company.

General users: Prompting engineers to think more about specific people during their design generation may help to avoid designing for the average (male) user. For example, women are significantly more likely than men to be injured in car crashes [80], [81], yet currently, crash dummies do not represent female body differences. Seat belt effectiveness for pregnant people have similarly received little attention [82]. Through considering more specifically who their design is for, engineering designers may become more aware of differences among the many people who use their designs to drive cars each day, a step towards preventing needless injuries and deaths.

This example illustrates the primary implication of this research: The need for more strategies to promote intentional and explicit consideration of people throughout design.

6. CONCLUSION

These findings suggest asking engineers to "keep people in mind" during concept generation can be encouraged through explicit representation of people within sketches. Adding this simple step during concept generation promotes consideration of "Who is this idea for?" and leads to deeper consideration of physical and social contexts, individual needs and values, and greater awareness that all designs are not necessarily "for everyone" because people, contexts, and values differ. The results suggest that the simple strategy of depicting people during concept generation aids in deeper consideration of the humans impacted in human-centered design.

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REFERENCES

[1] IDEO, *The Human-Centered Design Toolkit*. 2019.

[2] D. Norman, *The design of everyday things: revised and expanded edition*. Basic Books, 2013.

[3] A. Shum *et al.*, "Inclusive Design Toolkit." Microsoft Design, 2016.

[4] T. Brown, "Design Thinking," *Harvard Business Review*, pp. 84–95, 2008.

[5] C. B. Aranda-Jan, S. Jagtap, and J. Moultrie, "Towards a framework for holistic contextual design for low-resource settings," *International Journal of Design*, vol. 10, no. 3, 2016.

[6] M. R. Young, S. R. Daly, S. L. Hoffman, K. H. Sienko, and M. A. Gilleran, "Assessment of a novel learning block model for engineering design skill development: A case example for engineering design interviewing," presented at the 2017 ASEE Annual Conference & Exposition, Columbus, OH, Jun. 2017. Accessed: Jan. 15, 2018. [Online]. Available: https://peer.asee.org/assessment-of-a-novel-learning-block-model-for-engineering-design-skill-development-a-case-example-for-engineering-design-interviewing

[7] I. B. Rodriguez-Calero, M. J. Coulentianos, S. R. Daly, J. Burridge, and K. H. Sienko, "Prototyping strategies for stakeholder engagement during front-end design: Design

practitioners' approaches in the medical device industry," *Design Studies*, vol. 71, 2020.

[8] J. S. Dumas and J. C. Redish, *A Practical Guide to Usability Testing*, Revised Edition. Portland, Oregon: Intellect Books, 1999.

[9] E. B.-N. Sanders and P. J. Stappers, "Co-creation and the new landscapes of design," *CoDesign*, vol. 4, no. 1, pp. 5–18, Mar. 2008, doi: 10.1080/15710880701875068.

[10] T. Zhang and H. Dong, "Human-centred design: an emergent conceptual model," in *Include 2009*, London, Apr. 2009. [Online]. Available: www.hhc.rca.ac.uk/2084/all/1/proceedings.aspx

[11] OCAD University, "What is inclusive design," *Inclusive Design Research Centre*. https://legacy.idrc.ocadu.ca/about-the-idrc/49-resources/online-resources/articles-and-papers/443-whatisinclusivedesign (accessed May 02, 2023).

[12] S. Costanza-Chock, *Design Justice: Community-led practices to build the worlds we need*. MIT Press, 2020.

[13] E. B.-N. Sanders, "From user-centered to participatory design approaches," in *Design and the social sciences*, Taylor & Francis, 2002, pp. 18–25.

[14] C. DiSalvo, A. Clement, and V. Pipek, "Communities: Participatory design for, with, and by communities," in *Routledge International Handbook of Participatory Design*, Routledge, 2013.

[15] J. O. Wobbrock, S. K. Kane, K. Z. Gajos, S. Harada, and J. Froehlich, "Ability-based design: Concept, principles and examples," *ACM Transactions on Accessible Computing*, vol. 3, no. 3, 2011, doi: 10.1145/1952383.1952384.

[16] R. E. Freeman, *Strategic management: A stakeholder approach*. Cambridge University Press, 2010. [Online]. Available: https:// doi.org/10.1017/CBO9781139192675

[17] A. Khurana and S. R. Rosenthal, "Towards Holistic 'Front Ends' In New Product Development," *Journal of Product Innovation Management*, vol. 15, no. 1, pp. 57–74, Jan. 1998, doi: 10.1111/1540-5885.1510057.

[18] C. J. Atman, R. S. Adams, M. E. Cardella, J. Turns, S. Mosborg, and J. Saleem, "Engineering design processes: A comparison of students and expert practitioners," *Journal of Engineering Education*, vol. 96, no. 4, pp. 359–379, Oct. 2007, doi: https://doi.org/10.1002/j.2168-9830.2007.tb00945.x.

[19] G. Dieter and L. Schmidt, *Engineering design*. Boston: McGraw-Hill higher Education, 2009.

[20] S. Costanza-Chock, "Design practices: 'Nothing about us without us,'" in *Design justice: Community-led practices to build the world we need*, Cambridge, MA: MIT Press, 2020, pp. 69–101.

[21] G. Burleson, K. H. Sienko, and K. Toyama, "Incorporating contextual factors into a design process: An analysis of engineering for global development literature," in *Proceedings of the ASME 2020 International Design Engineering Technical Conference*, Aug. 2020.

[22] D. Schleicher, P. Jones, and O. Kachur, "Bodystorming as embodied designing," *Interactions*, vol. 17, no. 6, pp. 47–51, 2010.

[23] B. K. Smith, "Bodystorming mobile learning experiences," *TechTrends*, vol. 58, pp. 71–76, 2014.

[24] T. Miaskiewicz and K. A. Kozar, "Personas and user-centered design: How can personas benefit product design processes?," *Design Studies*, vol. 32, pp. 417–430, 2011.

[25] V. der L. Corrie, "The value of storyboards in the product design process," *Personal and ubiquitous computing*, vol. 10, no. 2, pp. 159–162, 2006.

[26] S. Seinfeld, T. Feuchtner, A. Maselli, and J. Muller, "User representations in human-computer interaction," *Human-Computer Interaction*, vol. 36, no. 5–6, pp. 400–438, 2021, doi: https://doi.org/10.1080/07370024.2020.1724790.

[27] D. W. Dahl, A. Chattopadhyay, and G. J. Gorn, "The importance of visualisation in concept design," *Design Studies*, vol. 22, no. 1, pp. 5–26, 2001, doi: https://doi.org/10.1016/S0142-694X(99)00028-9.

[28] E. Brunsen, W. B. Hicks, and A. C. McLaughlin, "Implications and methodological issues for the study of individual differences in usability and user experience," in *Handbook of Usability and User-Experience*, 1st ed.CRC Press, 2022.

[29] J. L. Szalma, "Individual differences in human-technology interaction: incorporating variation in human characteristics into human factors and ergonomics research and design," *Theoretical Issues in Ergonomics Science*, vol. 10, no. 5, pp. 381–397, 2009, doi: 10.1080/14639220902893613.

[30] LSA Inclusive Teaching, University of Michigan, "Social Identity Wheel." https://sites.lsa.umich.edu/inclusive-teaching/social-identity-wheel/ (accessed Jan. 30, 2023).

[31] D. Jacobson and N. Mustafa, "Social identity map: A reflexivity tool for practicing explicit positionality in critical qualitative research," *International Journal of Qualitative Methods*, vol. 18, pp. 1–12, 2019, doi: 10.1177/1609406919870075.

[32] P. Kuppers, "Crip/mad archive dances: Arts-based methods in and out of the archive," *Theater*, vol. 52, no. 2, pp. 67–77, 2022, doi: 10.1215/01610775-9662255.

[33] I. Lara, "Bruja positionalities: Toward a Chicana/Latina spiritual activism," *Chicana/Latina Studies*, vol. 4, no. 2, pp. 10–45, Spring 2005.

[34] L. L. Piepzna-Samarasinha, "Care Webs: Experiments in creating collective access," in *Care Work: Dreaming Disability Justice*, Vancouver: Arsenal Pulp Press, 2018.

[35] D. Bairaktarova, W. Z. Bernstein, T. Reid, and K. Ramani, "Beyond surface knowledge: An exploration of how empathic design techniques enhances engineers understanding of users' needs," *International Journal of Engineering Education*, vol. 32, no. 1, pp. 111–122, 2016.

[36] M. Kouprie and F. Visser, "A framework for empathy in design: stepping into and out of the user's life," *Journal of*

Engineering Design, vol. 20, no. 5, pp. 437–448, Oct. 2009.
[37] J. Noland and R. Phillips, "Stakeholder engagement, discourse ethics and strategic management," *International Journal of Management Reviews*, 2010, doi: 10.1111/j.1468-2370.2009.00279.x.
[38] C. L. Bennett and D. K. Rosner, "The promise of empathy: design, disability, and knowing the 'other,'" in *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, Glasgow Scotland Uk: ACM, May 2019, pp. 1–13. doi: 10.1145/3290605.3300528.
[39] J. Kujala, S. Sachs, H. Leinonen, A. Heikkinen, and D. Laude, "Stakeholder engagement: Past, present, and future," *Business & Society*, vol. 61, no. 5, pp. 1136–1196, May 2022.
[40] D. G. Johnson, N. Genco, M. N. Saunders, P. Williams, C. Conner Seepersad, and K. Holtta-Otto, "An experimental investigation into the effectiveness of empathic experience design for innovative concept generation," *Journal of Mechanical Design*, vol. 136, 2014.
[41] S. Raviselvam, D. Hwang, B. Camburn, K. Sng, K. Holtta-Otto, and K. L. Wood, "Extreme-user conditions to enhance design creativity and empathy-application using visual impairment," *International Journal of Design Creativity and Innovation*, vol. 10, pp. 75–100, 2022, doi: 10.1080/21650349.2021.2024093.
[42] A. Kafer, *Feminist, queer, crip*. Indiana University Press, 2013.
[43] T. Siebers, *Disability Theory*. University of Michigan Press, 2008.
[44] A. Flower, M. K. Burns, and N. A. Bottsford-Miller, "Meta-analysis of disability simulation research," *Remedial and Special Education*, vol. 28, no. 2, pp. 72–79, 2007.
[45] J. Strobel, J. Hess, R. Pan, and C. A. Wachter Morris, "Empathy and care within engineering: qualitative perspectives from engineering faculty and practicing engineers," *Engineering Studies*, vol. 5, no. 2, pp. 137–159, 2013, doi: http://dx.doi.org/10.1080/19378629.2013.814136.
[46] N. M. Sisson, E. A. Impett, and L. H. Shu, "Can induced gratitude improve creative performance on repurposing tasks?," *Journal of Mechanical Design*, vol. 144, 2022, doi: 10.1115/1.4052586.
[47] N. D. Fila and J. L. Hess, "In their shoes: Student perspectives on the connection between empathy and engineering," in *ASEE Annual Conference & Exposition*, 2016.
[48] M. Alsager Alzayed, C. McComb, J. Menold, J. Huff, and S. R. Miller, "Are you feeling me? An exploration of empathy development in engineering design education," *Journal of Mechanical Design*, vol. 143, 2021.
[49] M. Alsager Alzayed, S. R. Miller, and C. McComb, "Empathic creativity: can trait empathy predict creative concept generation and selection?," *Artificial Intelligence for Engineering Design, Analysis, and Manufacturing*, vol. 35, pp. 369–383, 2021, doi: https://doi.org/10.1017/S0890060421000196.
[50] D. H. Cropley, "The Role of Creativity as a Driver of Innovation," in *2006 IEEE International Conference on Management of Innovation and Technology*, Jun. 2006, pp. 561–565. doi: 10.1109/ICMIT.2006.262281.
[51] K. H. Dorst and N. Cross, "Creativity in the design process: co-evolution of problem-solution," *Design Studies*, vol. 22, no. 5, pp. 425–437, 2001.
[52] J. S. Higgins, G. C. Maitland, J. D. Perkins, S. M. Richardson, and D. W. Piper, "Identifying and solving problems in engineering design," *Studies in Higher Education*, vol. 14, no. 2, pp. 169–181, Jan. 1989, doi: 10.1080/03075078912331377496.
[53] N. Cross, *Engineering Design Methods: Strategies for Product Design*, 4th ed. West Sussex, England: Wiley, 2008.
[54] A. Osborn, *Applied Imagination: Principles and Procedures of Creative Problem Solving New York*. Scribner, 1957.
[55] G. Altshuller, *40 principles: TRIZ keys to technical innovation*. Worcester, Mass.: Technical Innovation Center, Inc., 1997.
[56] S. R. Daly, S. Yilmaz, J. L. Christian, C. M. Seifert, and R. Gonzalez, "Design heuristics in engineering concept generation," *Journal of Engineering Education*, vol. 101, no. 4, pp. 601–629, Oct. 2012.
[57] S. R. Daly, C. M. Seifert, S. Yilmaz, and R. Gonzalez, "Comparing ideation techniques for beginning designers," *Journal of Mechanical Design*, vol. 138, no. 10, p. 101108, Oct. 2016, doi: 10.1115/1.4034087.
[58] S. Yilmaz, S. R. Daly, C. M. Seifert, and R. Gonzalez, "Evidence-based design heuristics for idea generation," *Design Studies*, vol. 46, pp. 95–124, Sep. 2016, doi: 10.1016/j.destud.2016.05.001.
[59] V. Rao, E. Kim, J. Kwon, A. M. Agogino, and K. Goucher-Lambert, "Framing and tracing human-centered teams' method selection: an examination of decision-making strategies," *Journal of Mechanical Design*, vol. 143, 2021.
[60] V. Trucchia, "Story of a storyboard," *OpenLab at City Tech*, Sep. 10, 2020. https://openlab.citytech.cuny.edu/comd1112-fall2020-noriega/2020/09/10/story-of-a-storyboard/ (accessed Jan. 23, 2023).
[61] V. Braun and V. Clarke, "Using thematic analysis in psychology," *Qualitative Research in Psychology*, vol. 3, pp. 77–101, 2006, doi: 10.1191/1478088706qp063oa.
[62] V. Clarke and V. Braun, "Teaching thematic analysis: Overcoming challenges and developing strategies for effective learning," *The Psychologist*, vol. 26, no. 2, 2013.
[63] C. B. Zoltowski, W. C. Oakes, and M. E. Cardella, "Students' Ways of Experiencing Human-Centered Design," *Journal of Engineering Education*, vol. 101, no. 1, pp. 28–59, Jan. 2012, doi: 10.1002/j.2168-9830.2012.tb00040.x.

[64] G. Burleson, S. V. S. Herrera, K. Toyama, and K. H. Sienko, "Incorporating contextual factors into engineering design processes: An analysis of novice practice," *Journal of Mechanical Design*, vol. 145, 2023, doi: 10.1115/1.4055780.

[65] S. Hendren, *What Can a Body Do? How We Meet the Built World*. Riverhead Books, 2020.

[66] J. Treviranus, "Inclusive design: The bell curve, the starburst and the virtuous tornado," Apr. 21, 2019. https://medium.com/@jutta.trevira/inclusive-design-the-bell-curve-the-starburst-and-the-virtuous-tornado-6094f797b1bf (accessed May 12, 2023).

[67] T. Rose, "When U.S. air force discovered the flaw of averages," *Toronto Star*, Jan. 16, 2016. Accessed: Jan. 26, 2023. [Online]. Available: https://www.thestar.com/news/insight/2016/01/16/when-us-air-force-discovered-the-flaw-of-averages.html

[68] A. Hamraie, *Building access: Universal design and the politics of disability*. University of Minnesota Press, 2017.

[69] R. Garland-Thomson, "Misfits: A Feminist Materialist Disability Concept," *Hypatia*, vol. 26, no. 3, pp. 591–609, 2011, doi: https://doi.org/10.1111/j.1527-2001.2011.01206.x.

[70] Design Justice Network, "Design Justice Network Principles," 2018. https://designjustice.org/read-the-principles (accessed Jan. 26, 2023).

[71] D. G. Jansson and S. M. Smith, "Design fixation," *Design Studies*, vol. 12, no. 1, pp. 3–11, 1991.

[72] E. C. Hilton, J. Linsey, W. Li, and T. Hammond, "Effectively teaching sketching in engineering curricula," *International Journal of Engineering Education*, vol. 34, no. 2B, pp. 644–652, 2018.

[73] E. C. Hilton, T. Gamble, W. Li, T. Hammond, and J. S. Linsey, "Back to basics: Sketching, not CAD, is the key to improving essential engineering design skills," in *International Design Engineering Technical Conferences and Computers and Information in Engineering Conference*, American Society of Mechanical Engineers, 2018.

[74] G. Lee, S. Hwang, and D. Lee, "Improvements of warning signs for black ice based on driving simulation experiments," *International Journal of Environmental Research and Public Health*, vol. 19, no. 12, 2022, doi: 10.3390/ijerph19127549.

[75] C. K. Thorbole, "Seatbelt submarining injury and its prevention countermeasures: How a cantilever seat pan structure exacerbate submarining," *Journal of Family Medicine and Primary Care*, vol. 4, no. 4, pp. 587–590, 2015, doi: 10.4103/2249-4863.174299.

[76] BBC News, "Tokyo 2020: Toyota restarts driverless vehicles after accident," Aug. 31, 2021. Accessed: Jan. 31, 2023. [Online]. Available: https://www.bbc.com/news/business-58390290

[77] P. McCausland, "Self-driving Uber car that hit and killed woman did not recognize that pedestrians jaywalk," *NBC News*, Nov. 09, 2019. Accessed: Jan. 31, 2023. [Online]. Available: https://www.nbcnews.com/tech/tech-news/self-driving-uber-car-hit-killed-woman-did-not-recognize-n1079281

[78] J. Miley, "Autonomous cars can't recognize pedestrians with darker skin tones," Apr. 21, 2021. https://interestingengineering.com/culture/autonomous-cars-cant-recognise-pedestrians-with-darker-skin-tones (accessed Jan. 31, 2023).

[79] M. Frank, "Engineering systems thinking and systems thinking," *Systems Engineering*, vol. 3, no. 3, 2000.

[80] D. Bose, M. Segui-Gomez, and J. R. Crandall, "Vulnerability of female drivers involved in motor vehicle crashes: An analysis of US population at risk," *American Journal of Public Health*, vol. 101, no. 2, 2011.

[81] J. Forman *et al.*, "Automobile injury trends in the contemporary fleet: Belted occupants in frontal collisons," *Traffic Injury Prevention*, vol. 20, no. 6, pp. 607–612, 2019.

[82] C. J. Vladutiu and H. B. Weiss, "Motor vehicle safety during pregnancy," *American Journal of Lifestyle Medicine*, vol. 6, no. 3, pp. 241–249, 2012, doi: 10.1177/1559827611421304.