DECODING TACIT KNOWLEDGE IN TECHNICAL DESIGN

A Thesis

Presented to the Faculty of the Graduate School

Of Cornell University

In Partial Fulfillment of the Requirements for the Degree of

Master of Arts

By

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December 2022

ABSTRACT

This study attempted to understand fit sessions in the apparel product development process and focused on capturing the tacit knowledge of technical design team members. Because fit sessions have not been studied thoroughly as they were considered company secrets, the study also proposed a new framework for documenting the fit session decision-making process, which combined the team mental model and seeing-moving-seeing methods. Data collection included one case study of fit session observation with follow-up interviews and individual interviews with five fit models. Participants of the study were recruited by snowball sampling and word of mouth. The findings provided a broad set of insights around the tacit knowledge of technical designers and fit models and how they make decisions during fit sessions. It was found that to solve garment fit issues, technical designers had priorities in resolving them as some of these solutions derived from misfit cases observed on different garments. The power dynamics in the fit sessions kept changing as each fit session participant had their own professional knowledge. This study also highlighted the various topics discussed in fit sessions. These insights could be beneficial for the fashion technology industry as they develop new technologies to support the apparel product development process, as well as for the apparel brands as they develop a competitive edge through utilizing stored tacit knowledge to simplify fit sessions.

BIOGRAPHICAL SKETCH

Yoon Yang was born in Seoul, South Korea, in 1995. She attended Ewha Womans University and graduated in August 2019 with a Bachelor of Science degree in Clothing and Textiles. During her college years and after her graduation, Yoon worked in trade shows as a sales representative specializing in custom design orders. Simultaneously, she ran her own business related to fashion developing customized/tailored ensembles of garments for individual customers. Through years of experience, Yoon got more interested in product development and garment-body relationships. She started her graduate study in the Department of Human Centered Design at Cornell University in 2020 and is a part of the Digital Fashion and 3D Body Scan Lab research team. Yoon's research interest includes patternmaking techniques and the psychology behind fashion. Her current research focuses on understanding fit alteration and fit session dynamics.

ACKNOWLEDGEMENTS

I would like to thank Dr. Fatma Baytar for her clear, focused and supportive guidance and feedback throughout the process. I deeply appreciate all that she has done for me. I would like to acknowledge her for supporting me as my creative but random ideas turn into beautiful gems. I also would like to thank Dr. Lee Humphreys, my minor committee member in the Department of Communication, for her feedback, support, and encouragement.

I would like to thank the Cornell Center for Social Sciences, which partly funded my trip to the apparel company, at which fit session observations and some of the interviews took place. It was a great help for me as I conducted on-site observations and interviews.

I also want to thank my parents for always standing by me. Lastly, I want to thank my team members in the Digital Fashion and 3D Body Scan Lab at Cornell. Thank you all for supporting me, feeding me, encouraging me, and loving me every moment.

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CHAPTER 1

INTRODUCTION

1.1. Statement of the problem

The purpose of this study was to understand the decision-making process in fit sessions during apparel product development and dictate the tacit knowledge within the process regarding fit analysis and pattern adjustments. The fit sessions have not been studied due to their complexity and because apparel companies consider them company secrets as they include targeting customer specs and know-how of how they develop a garment.

1.2. Significance of the study

Fit sessions are where apparel companies meet their fit standards in apparel product development stages. According to Ashdown and O'Connell (2006), clothes that fit well have positive psychological impacts on wearers as they enhance their appearance and increase confidence. Well-fitted garments look better and are perceived to be more comfortable, whereas the opposite will not be worn or selected in the market (Gill, 2011). Fit testing and analysis in product development stages are important because they lead directly to designing well-fitted garments, which bring consumer satisfaction with the fit. Companies that bring the best results over their repetitive fit testing can release better-fitting garments and guarantee higher sales (Bye & LaBat, 2005).

Many new technologies such as 3D body scanning and 3D digital prototyping have been developed and are being used in the fashion industry. On the other hand, fashion-related research, including investigations of fit sessions, has not been conducted thoroughly to guide the development of technology or make use of it. Therefore, recent new technology development in fashion mostly focuses more on mere technical development such as flawlessly visualizing fabric properties physics-wise, instead of considering garment-human interactions in 3D simulations. In this case, technical improvement makes no use in the industry because they disregarded the fact that the garment is made to be worn on moving bodies and may change its shape and vice versa. Investigating fit sessions would help us pin down when and how we should support specific apparel product development stages with current and future technology.

Moreover, people participating in fit sessions are experts in their own way and the knowledge they have is considered tacit as it is hard to explain and could only be explained in a certain context. Years of experience in the field have been accumulated individually and everyone in fit sessions shares their opinions on fit alterations. However, as these tacit solutions are not collected as well as each person has a different level of knowledge, it is difficult to meet an agreement during the fit sessions and must go through trials and errors by making myriads of new samples to find the correct answer. Recording fit sessions would turn the apparel product development process more effective and the data collected could also be used to educate the future workforce in the fashion industry.

This research focused on the product development division of fashion where ages of tacit knowledge have been accumulated. Although much new technology has been utilized in the fashion industry to support the fit testing process, none of them clearly helped simplify the process. Because the ultimate tacit knowledge hub is the fit session among apparel product development stages. However, fit sessions have not been studied thoroughly because they are considered to have company secrets. Fit sessions are where a team of professionals such as designers, technical designers, fit models, and other associates (e.g., merchandisers) gather in person and have discussions on how to improve the sample garment to meet the fit standard. Iterations continue until each team member confirms the fit of a sample garment. As fit sessions are conducted between designing the garment and manufacturing, the knowledge shared over the stage includes both aesthetic and practical comments. Fit models' comments related to the comfort and tactile properties of the garments tested also play an important role in identifying existing fit issues.

1.3. Definitions of terms

Product development	"the creation of new apparel products for production" (Lee & Steen, 2014)
Technical design	"technical design involves analyzing designs and design details, creating and editing CAD sketches for accuracy, understanding how the garment should fit, working with the factory to communicate precisely what is wanted, confirming all the details, and acting as the last pair of eyes on the tech pack before it is sent out for [mass] production" (Lee & Steen, 2014, p.35)
First sample	"the original sewn prototype of a new design created from a drafted or draped pattern to test fit, function and aesthetic appeal" (Bubonia & Kontzias, 2011, p.183)
Second sample	The second sample is the revised version of the first sample based on the corrections made during the initial fit session (Lee & Steen, 2014)
Production sample	"The final sewn sample that has been corrected, perfected and tested for fit, function, and aesthetic appeal." (Bubonia, 2012, p.183)

First pattern	"An original or initial pattern developed for a design that includes seam and hem allowances" (Bubonia, 2012, p.187)
Sample size	"A manufacturer's designated size for dress forms, fit models, first pattern development and prototypes" (Bubonia, 2012, p.183)
Fit session	"it is the meeting to compare all the variables and then determine what changes need to be made for the next sample" (Lee & Steen, 2014, p.353)
Fit	"the relationship between the human form and the garment form" (Liechty, Rasband,& Pottberg-Steineckert,,2016, p.47)
Good fit	"the contours of the garment must conform closely to the contours of the body." (Liechty, Rasband,& Pottberg-Steineckert,,2016, p.47)
Comfort	"the sensation of contented well-being and the absence of unpleasant feelings" (Fuzek & Ammons, 1977, p. 121).

CHAPTER 2

LITERATURE REVIEW

2.1. Overview

When Covid-19 hit the U.S. in March 2020, apparel companies had to switch to using 3D CAD programs to develop garment prototypes. They were neither able to invite fit models to their headquarters nor meet as a design team in person. Virtual prototyping can be a solution to this problem, and digitalization is moving forward fast in the post-pandemic era. Virtual prototyping of garments has been used in various stages of apparel product design. By using 3D virtual prototyping, apparel companies can reduce both the time and the cost spent on developing numerous sample garments (Ancutiene, 2014). Many apparel companies were reported to be switching over from physical models to virtual avatars since the virtual technologies offer them more flexibility to customize parametric avatars with new measurements (Balach et al., 2021). Draping digital garments onto virtual avatars to visualize the garment appearance in 3D, along with realistic fabric simulations, enable companies to check the fit and patterns very quickly to make improvements. Simulations reduce the dependency on physical prototyping and shorten the product-development lead time as well as the associated costs when communicated virtually (Jankoska, 2020), thus increasing the competitiveness of apparel companies (Paunović, 2018).

There is constant pressure in the industry for simplifying product-development stages and minimizing the investment in physical prototyping to deal with rapid fashion changes and reduce costs. Although 3D technologies have many advantages as described above, virtual prototypes still do not fully resemble actual prototypes in many ways (Ashmawi et al., 2021; Kuijipers et al., 2020). There are some limitations including a lack of realism in fabric drape properties and a lack of accurate material properties regarding human bodies to conduct geometric modeling of human bodies (Harrison et al., 2018). How fabric drapes are based on several factors such as fiber, yarn, and fabric structures, its grain direction, and whether the fabric is seamed or not. Even more important is how a fabric responds to its surroundings, like how it stretches under contact with human skin or how it looks in different lighting. The properties of fabrics must be considered when developing the right fabric simulation (Jevšnik et al., 2017; Jevšnik et al., 2014). Garment simulations have been successful when simulating sample garments style/design-wise but not functionality-wise. Therefore, additional research needs to be conducted to distinguish how to improve the software and human-computer interactions to manage digital fit testing. As a result, the current study aimed at investigating in-person apparel fit sessions and interactions among the individuals engaged in the process in the hope of improving software programs and digital experiences.

The most important approach in deciphering such interactions is understanding the tacit knowledge embedded in the problem-solving stages that happen at each fit session interaction. The following sections explain the fit process, define tacit knowledge that could be extracted to better understand the dynamics behind fit sessions, and suggests existing theoretical frameworks that could serve as a roadmap to better explain the process.

2.2. Garment fit and fitting: Tacit knowledge in apparel product development

Fit

Clothes take an important part in our lives not only because they are used to cover and protect our bodies but also used to identify ourselves (Alexander et al., 2005). According to Ashdown and O’Connell (2006), clothes that fit well have positive psychological impacts on wearers as they enhance their appearance and increase confidence. Well-fitted garments look better and are perceived to be more comfortable, whereas the opposite will not be worn or selected in the market (Gill, 2011). "Companies that best understand their target customer's desires and expectations for fit are the best equipped to provide the fit they want. Consistent fit is an important element for apparel within a given brand, and is also essential for building customer loyalty" (Lee & Steen, 2014, p.331).

There are five elements of fit that must be considered when evaluating a garment: ease, balance, set, grain, and line (Erhwin & Kinchen, 1969). Ease is "the difference between the measurement of garment and the measurement of the wearer at any given point, at the hip, for example. There are two types of ease- fit ease and design ease. Fit ease is for ordinary movement and design ease is added or removed to emphasize a certain silhouette" (Le & Steen, 2014, p.331). Balance can be defined by its relation to fabric grainline and garment structural style lines (Lee & Steen, 2014). As Lee and Steen (2014) detail, "the length grain should run parallel to the length of the body at the center front and center back, down the center of the arm from shoulder to the elbow, and down the center front of each leg. The [fabric] crosswise grain should run perpendicular to the length of the body at bust and hip" (p.339). Set is "a smooth fit of garments without any unwanted draglines or wrinkles. A garment that does not fit well on the body will be unattractive way and indicates either not enough or an excess of ease. "Generally, draglines will point to the problem area" (Lee & Steen, 2014, p.339).

Designers/ Fashion Designers

Designers keep track of fashion trends and forecast to release garments that customers would love in the market. They are essential in visualizing their creative works based on their brands' identity, targeting customers, and production capacity. They are the first players to start apparel product development but play the longest game as their works are closely related to every stage of product development, including manufacturing and merchandising (Bubonia, 2012).

Technical Designers

Technical Designers, also known as patternmakers, are responsible for developing patterns by using manual or digital methods of flat patternmaking, draping, or reverse engineering while "checking for interpretation of design and accurate fit" (Bubonia, 2012, p.189). After the concept and look are designed, the next step is to create the first sample to evaluate garment fit and construction. Once a technical package (i.e., tech pack) is prepared and sent to the manufacturer/ or in-house sample room, the first sample is prepared and sent to the design team for further iterations to perfect fit. (Lee & Steen, 2014).

Fit sessions

During fit sessions, designed garments are determined whether their looks fit into the brand's overall design aesthetics and eventually could appeal to target markets. (Lee & Steen, 2014). Fit sessions in product development stages are important because they lead directly to designing well-fitted garments, which bring consumer satisfaction with the garment fit. Companies that bring the best results over their fit sessions can release better-fitting garments and guarantee higher sales (Bye & LaBat, 2005). In the apparel product development process, fit models, who are in the shape and size of the target customers, try on sample-size garments during fit sessions. The apparel product development team usually holds 2-4 rounds of fit sessions to confirm the design and fit of the garments. Designers, merchandisers, and pattern makers test the fit of the sample size garments and collect both visual and comfort feedback (Baukh, 2021; ClothierDesignSource, 2020). They may reflect or reject this feedback to 2D garment patterns to improve fit and overall satisfaction (Bye & LaBat, 2005).

A fit session is "a meeting between the design and technical teams where they assess the fit of a collection" (Otomoso, 2018). During physical fit sessions, even though fit models, designers, merchandisers, and pattern makers evaluate the prototype garments regarding fit, comfort, and functionality (Kohn & Ashdown, 1998; Otomoso, 2018), the main actors for decision-making are designers, technical designers, and fit models. One of the fit model interviewees in Ilyashov's (2018) article related the actors in fit sessions to a group of architects and engineers where designers plan garments and technical teams build them. Individuals engage in fit assessment and agree on pattern alterations during the sessions (Bye & LaBat, 2005; Choi & Ashdown, 2002). Otomoso (2018) suggested spending 20 minutes per garment during the first fit sessions and less amount of time per garment in the following sessions.

When the sample garments are marked in detail in tech packs including trims and fit, they are sent to manufacturers upon approval to confirm the final orders (The Fashion Business Couch, 2017). Fit sessions are recorded in various ways: photos, videos, and by taking notes (Kohn & Ashdown, 1998; Petrova & Ashdown, 2012; Schofield et al., 2006). Visual documentation highlights where in garment makes issues regarding fit whereas written records are used to give details and comments on how these issues could be resolved. The written records can use detailed technical terms (Ashdown & Connell 2006) or informal terms depending on the individuals who evaluated the fit (Shin & Damhorst, 2018). Therefore, the evaluation of fit is frequently subjective as well as pattern alteration decisions to resolve fit issues on garments. Additionally, the written documentation's elaboration quality is impacted by "tacit knowledge", which is complex knowledge acquired by technical designers over the years and specific to certain garment designs, body shapes, or fabrics (McKinney et al., 2012). Not recording fit and pattern alteration clearly is a very typical practice in the apparel industry because successful alteration methods are considered trade secrets or the genius of an individual in the fashion industry (Breslin & Buchanan, 2008). After each fit session, designers and technical designers update the fit history with fit comments. When the comments are delivered to factories, they prepare a new version of the garment based on the comments (Lee& Steen, 2014).

Fit models

Fit models are preferred for working with dress forms because they can evaluate the comfort of the garment and give comments on tactile experience in both static and motion (Bougourd, 2007; Lee & Steen, 2014). Fit models usually represent target customers of the clothing brands to check the garment, not only the fit but also the details of the garments including trims (Clothierdesignsource, 2020). Unlike runway models who represent only a small fraction of bodies, fit models are recruited to test the garment meant for manufacturing clothes to be sold in retail targeting a wide range of customers (Petite Poire, 2017). Fit models should be experienced enough and give quality comments in fit sessions to make sure the company gets useful feedback from the wearer’s perspective. One or two models are assigned per single garment design; therefore, fit tests are limited to a few basic sizes, i.e., small and medium sizes. Also, there are time and cost limitations for fit testing.

Fit models can usually test 8 to 20 garments per visit, and it is usually difficult to evaluate every garment in detail. As a result, fit sessions are held repetitively to make sure the fit issues are resolved (Campbell et al., 2021). Over ninety percent of garments in fit sessions are evaluated on fit models two to three times during the product development process (Bye & LaBat, 2005). While the garments should be fit tested on different sizes from the smallest to the largest, this is done seldomly due to the complicated iterative process as well as the increased costs (Watkins & Dunne, 2015). Therefore, extended sizes are usually only checked by measurements without going through the fit sessions with fit models (Ashdown & O'Connell, 2006).

Ilyashov (2018) explains that fit models play an essential role in fit testing which is closely related to market sales of the clothing. As they help the apparel team approve or reject the initial designs and length of the garment, the fitting process eventually reduces the fit-related returns in retail when the garments are released. Those who could communicate with technical jargon were considered professionals in the industry (Ilyashov, 2018). When fit models evaluate garments, they do through the garment fitting process as general customers and comment on whether it was easy to put on or the pockets are useful. They also walk and move their bodies to see if the garment feels comfortable. They also are professionals in garment development as they comment on how each design element functions and bring their knowledge such as how specific ease amount affects a certain part of the garment (Lee & Steen, 2014).

Besides commenting on garments, maintaining correct postures during the process is also necessary for fit models. Not only are the size 6 or 8 fit models important, but models of every size from 00 to 24 to ensure the garments have been graded accurately (Ilyashov, 2018). Another interviewee of her article, Mr. Jac Cameron, AY's co-founder and creative director, said, "Hyper-specific feedback is integral to achieve a fit that moves with the body, provides comfort to the wearer, and ultimately inspires confidence. This level of input during crucial stages of garment fittings helps us assess whether a design element needs to be changed or modified in any way". As a result, it can be inferred that fit models are also a part of tacit knowledge creation and therefore are essential in the process.

Omotoso (2018) stated that apparel companies should choose their fit models based on their customer's profiles. Fit models could also be considered 'live mannequins' that have preferred measurement specifications that designers or manufacturers want (Model Scouts, n.d.; Peach Fitting Models, n.d; Petite Poire, 2017). Although fit models cannot represent every single customer, they should share similar anthropometric features with the target customers for example by keeping the fit models within the same age range as the target customers (Omotoso, 2018). Moreover, fit model sizes are usually the middle size of the customer sizes range (Sample Room, 2015). Fit models should be able to point out fit issues while maintaining balanced bodies with the same measurements (Model Scouts, n.d.; Peach Fitting Models, n.d.).

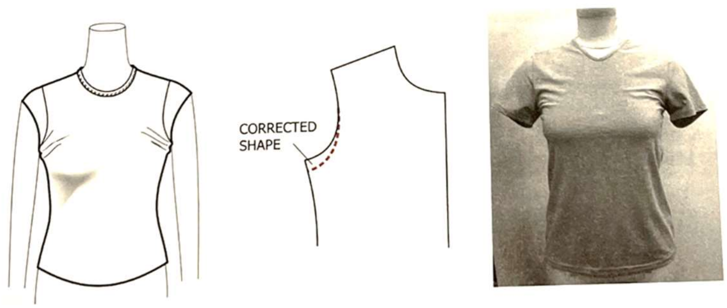
Apparel fit evaluations and problem-solving: Pattern alterations

All five elements of fit are detected by fit observers such as technical designers and designers. The set of the garment in hidden areas like underarm or crotch could also be verified by the wearers in fit sessions, such as fit models. Fit issues happen when one or more of the five elements of fit are not met (Erhwin & Kinchen, 1969). In this case, fit of a 3D garment must be adjusted by making corrections to its 2D patterns. When fit issues are identified, patterns are modified to improve fit. Pattern alterations might include adjusting seam lines to change the outer edges of the pattern blocks or modifying main structure lines such as bust, waist, and hip lines within the pattern blocks. Either way could be chosen depending on the fit issues and intended fit results (Wang, 2008). Figure 1 shows an example of the detected draglines as a visual clue to misfit and the suggested pattern changes.

It is worth to mention that apparel fit evaluations discussed throughout the thesis refer to subjective evaluations conducted by people (e.g., technical designers) who observe visual fit clues and people (e.g., fit models). who experience fit There are methods to evaluate apparel fit objectively, which would require the use of computer-aided design (CAD) software such as Geomagic Wrap, Optitex, CLO, VStitcher, etc. and/ or 3D body scanning technology.

Figure 1

Armhole drop is too high and causes tight draglines radiating at underarm (Lee & Steen, 2014, p. 343)



Digital models created by these technologies can be evaluated to measure the distances between body and garment at certain locations (e.g., bust, waist and hip) (Bi et al., 2022), volume differences as well as tension maps to show the looseness/ tightness of a virtual garment on a 3D digital avatar. These maps indicate the degree of external pressure on garments displayed in colors and give a numeric value at the selected areas. However, existing research indicates that fit assessments through tension maps are currently not reliable because 3D rigid avatars cannot resemble fat distributions of the human body to mimic the fit of the physical garment (Harrison et al., 2018; Rudolf et al., 2021).

2.3. Tacit knowledge

As often seen in apparel fit session settings; skills, proficiency, techniques, know-how, or expertise are not verbalized directly during working on a particular task but instead are manifested themselves as problem-solving. Polanyi (1958) identified this situation as tacit knowledge. Researchers tried to define tacit knowledge but none of them could solely pin down the definition. They added detailed explanations instead and tried to explain the concept by its features (Polanyi, 1962; Howells, 1996; Nonaka, 1991). As Polanyi (1966) stated, tacit knowledge is personal knowledge and individuals appear to know more than they could describe. It has several characteristics, which include the fact that it is difficult to document (Nonaka, 1991); personal knowledge is an important factor (Nonaka, 1991; Sternberg, 1994); it describes a process, i.e., know-how (Kogut & Zander, 1992; Nonaka,1991); and it is context-specific (Sternberg, 1994). Because tacit knowledge has a cognitive dimension, it follows certain thought processes of individuals when executing an action. As Sternberg (1994) indicated, tacit knowledge is job-specific or situation-specific and requires an individual's "commitment" to a "craft of profession" (Nonaka, 1991, p.98). Tacit knowledge is also associated with technical skills, which are "informal and hard to pin down" (Nonaka 1991, p. 98).

Spender (1996) resembles learning tacit skills to osmosis. One could transfer their tacit knowledge by showing them without communicating through language. One doesn't need to take the degree of background knowledge or prior experience of learners into consideration as transporting takes place in a specific context without noticing it. Therefore, the conveying tacit skill could resemble osmosis as it naturally moves from the expert to the apprentice (Spencer, 1996). Tacit knowledge develops over time (Leonard-Barton, 1992), and is acquired through "practice and experience" (Buckley, 2012; Ravetz, 1971). To make tacit knowledge accessible to others, it is important to make it explicit as it is embedded in people's heads and thoughts (Maravilhas & Martins, 2019). Tacit knowledge is difficult to express by individuals because it is deeply embedded in them because of context-based learning, which occurs after following certain rules or actions to practice. As Ravetz (1971) expresses, tacit knowledge is tied to the knower/performer. Individuals cannot usually explain the systematic rules they followed which are only known to them based on their personal knowledge and the background (Polanyi, 1962).

Nonaka and Takeuchi (1995) added that explicit knowledge, on the other hand, is sequential knowledge of there and then, highlighted that explicit knowledge is transmittable without context. Therefore, explicit knowledge is mostly obtained from information that has already been documented and through formal education (Maravilhas & Martins, 2019). It could be gathered in books, patents, articles, and other scripts (Maravilhas & Martins, 2019). Explicit knowledge could be collected and applied when the knowing personnel, who has the knowledge, don't exist on site (Lam, 2000).

Tacit knowledge is essential to the entire problem-solving process including detecting problems, finding proper solutions, and making predictions. Shirley and Langan-Fox (1996) related intuition to tacit knowledge when it comes to problem-finding and stated that intuitive problem-defining often brings insight into the sole nature of superficial issues. Accordingly, Leonard and Sensiper (1998) agreed that creative problem-finding based on tacit knowledge results in completely new solutions as it generates questions from a different angle. Richman and other researchers (2014) explained the problem-solving skill, which is tacit knowledge, concentrated referring to the performance of expert and novice chess players. Experts solve issues more easily because they have sets of experience and organized steps of actions/thoughts that they could draw on (Richman et al., 2014). The tacit knowledge of experts not only helps them define the issue but find the path to resolve it faster and easier. And the application of tacit knowledge in predictions was also found effective and it occurs on top of a significant level of accumulation of prior experience. Green (2012) found that nursing intuition, which is in other words intuitive but reasonable predictions of patients, is based on tacit knowledge and embodied actual practices. It allows both patients and nurses to meet the best results and the entire process of applying simulated solutions adds up to the hands-on experience of nurses which again supports tacit knowledge and nursing intuition (Green, 2012).

Polanyi (1958) first introduced a concept, “personal knowing”, which was the broader concept of tacit knowledge, insisting that any knowledge that has once accumulated within individuals has gone through a process of fully digesting it over their own experience (Polanyi, 1958). Therefore, all knowledge has its tacit aspects (Polanyi, 2009). Besides many terms that describe the performance of tacit knowledge, such as skill or know-how, Polanyi (1962) referred to the practice of tacit knowledge as art. The art cannot be transmitted by written instructions but only through passing down the connoisseurship over the years of practice and it also is limited to personal contacts. Therefore, art that has not been transmitted or used over a generation disappears and it may not be recovered regarding how it is usually transferred (Polanyi, 1962).

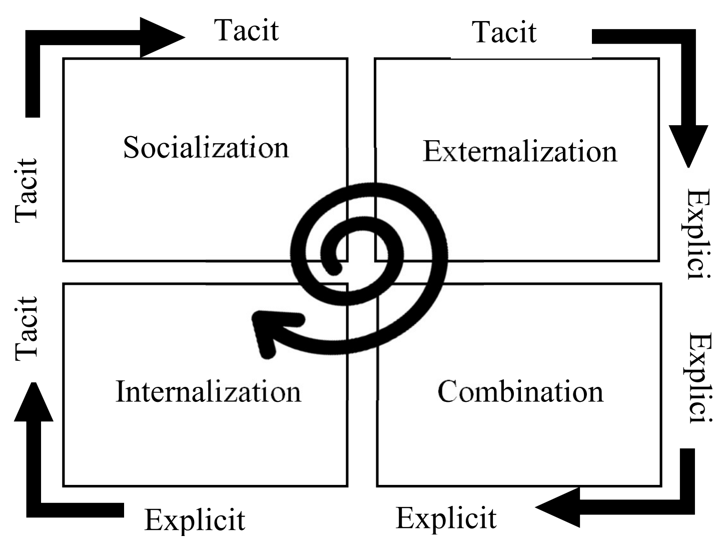
According to Polanyi (1962), knowledge has two units, explicit knowledge, and tacit knowledge. Explicit knowledge is knowledge of truths that could be easily transferred by learning through written forms (Polanyi, 1962). However, explicit knowledge and tacit knowledge are not antonyms, but it lies on each end of the spectrum. Most knowledge consists of both the explicit aspects and tacit aspects at the same time and either aspect develops through social interaction (Nonaka & Takeuchi, 1995). In addition to what Polanyi (1962) mentioned about transferring the practice of tacit knowledge, Nonaka and Nishiguchi (2001) implied that the utilizing and transmitting tacit knowledge occurs within socialization. They developed the discussion about tacit knowledge from the personal level to the organizational level while implementing socialization into organizational relationships. Moreover, Nonaka and Teece (2001) explained how knowledge is created based on the conversions of knowledge between tacit and explicit knowledge, stressing the importance of externalizing personal tacit knowledge.

Externalizing personal tacit knowledge refers to the creation of new explicit information (Nonaka &Teece, 2001).

When new organizational knowledge is created, personal tacit knowledge goes through the process of socialization, externalization, combination, and internalization, the SECI process (Figure 2) (Nonaka & Teece, 2001). Workers share personal experiences within the organization and externalize them by documenting them with words. Externalized tacit knowledge goes through a reassuring process by the workers as they merge the new one with the existing knowledge they already have and become concrete. Workers learn concrete new knowledge and internalize it. The following actions and performance of workers are based on the 'personalized' new knowledge (Nonaka & Teece, 2001). Repetitive SECI processes accumulate knowledge of individuals into organizational knowledge, and it helps organizations to stay successful (Nonaka & Takeuchi, 1995).

Figure 2

The SECI process (Nonaka et al., 2000)



Many areas such as engineering, computer science, biology, business, and nursing tried to understand the tacit dimensions of their fields to make use of it. How knowledge is created, shared, and managed has been studied to improve humans' lives in every aspect. In engineering, Cárcel-Carrasco et al. (2020) interviewed over 200 staff in the agri-food industry while performing a direct observation to understand maintenance engineering and the tacit knowledge behind it. The result showed that using the tacit knowledge learned over the process brought improvement in the company and the entire process of gaining and transferring knowledge was promoted when the company had an open organizational culture (Cárcel-Carrasco et al., 2020). This was derived from the fact that the transfer and production of knowledge were self-motivated, and it mostly happened over face-to-face communications when done informally. The tacit knowledge has been used not only to understand the overall work environment but to plan how to utilize the resource. They also pointed out the need for "knowledge managers" who have a sufficient level of experience in a field to identify the most efficient ways to handle the situation in terms of knowledge production. The researchers highlighted that it is important to show individuals that their knowledge could be applied to multiple different situations because it motivates individuals to obtain and produce more knowledge (Cárcel-Carrasco et al., 2020). It was noted that knowledge management should accompany application examples in those fields of industry where tacit knowledge acquisition and application happen simultaneously.

Segawa et al. (2016) conducted a case study of an electronics manufacturing service to navigate an effective way of communicating between design and production engineering by sharing tacit knowledge of their fields during the process. As electronic industries separate the design development stage and manufacturing stage while outsourcing the latter, communication between the two departments has been essential to meet both the quality and lead-time. During the process, knowledge creation and sharing took a considerable part (Segawa & Ikawa, 2012), especially the collaboration between 'production engineers' who have rich tacit knowledge in both design and manufacturing engineering and 'designers' who could accompany suggestions and know-how into their own revolutionary designs. Engineer's tacit knowledge got explicit by suggesting design guidance for designers in a way to enhance the performance of a newly developing product and designers incorporate the suggestions to come up with distinguishable but doable designs (Segawa et al., 2016). This process can be related to the new apparel product development process, which encounters issues regarding both creative design and mass production.

In computer science, the area has traditionally been working on deciphering tacit knowledge in the pursuit of improving artificial intelligence. Lam (2022) applied the concept of tacit knowledge to understand and comprehend complex structures of artificially intelligent (AI) systems. How the AI process the inputs are processed went unknown even to the designers who built the systems as it turned extremely intricate, and it led the system to be unreliable (Lam, 2022). Tacit knowledge and AI systems have things in common; tacit knowledge is implicit as one is not aware of one's thought processes behind the action and AI systems keep the data processing unknown in the black box. To provide sufficient explanation to make the AI explainable and reliable, Lam (2022) implemented a 'casually systematic process' delineating both initial factors and internal rules in the AI system which could be referred to as 'eliciting tacit knowledge to identify the black box.

In biology, getting local tacit knowledge regarding wildlife in certain areas has helped a lot in conservation planning. For example, Needham et al. (2020) collected tacit knowledge from local hunters, farmers, and lumberjacks to identify initial wildlife species habitat and pathways they usually take to build ecological corridors (Needham et al., 2020). During the process, they compared preexisting environmental science study results with the local tacit knowledge and turned out that the general studies explained some common features of wildlife within the area but also revealed clear difference, which was area specific. Although previous studies predict the most cost-beneficial ways to develop corridors, the issue consists of habitats of that wildlife which has not been covered in previous studies and human infrastructural demands. The local tacit knowledge has been collected through individual interviews and by mapping their knowledge on the map and the accumulated individual knowledge has been confirmed through workshops which were open focus-group discussions. Local tacit knowledge included more up-to-date information with interdisciplinary understandings of the human-ecology relationship. The tacit knowledge was made explicit by visualizing habitats and pathways on the map and made it possible to compare with quantitative data such as roadkill frequencies, which represented the failure in ecological connectivity (Needham et al., 2020). It was noted that local tacit knowledge not only confirmed the formal studies but also provided unexpected issues based on a rich personal database considering both wildlife and human activities. It also contributed to knowledge production by documenting and making it available in transferable data format.

In business field, big data helps organizations to build meaningful patterns and eventually leads the organizations to make evidence-supported decisions when predicting individual customers' buying behaviors or market trends (Acharya et al., 2018). It is essential to engage both the personal knowledge of employees and individual customers' knowledge in the knowledge co-creation to support the big data. Those companies, expecting to take the most out of big data, focus mainly on how to acquire valuable knowledge and incorporate them all into a database regardless of by whom they are produced. In terms of the integration of knowledge, organizations should take the fact that most knowledge is “socially co-created” (Acharya et al, 2018, p.92) into consideration. Moreover, Acharya et al. (2018) summarized that knowledge, player interaction, and individual actions were closely attached to each other. An individual’s intention to investigate what they confront is their natural trait to gather information and produce personal tacit knowledge to survive. The co-creation of knowledge highly relied on the trait and the communication between players within the organization and with customers.

In the fashion industry**,** the research pertaining to knowledge creation and management is examined through the lenses of fast fashion, knowledge management, retail, and product design processes. McCaffrey (2013) explains that when U.S. textiles and clothing companies had vertical production (i.e., all the steps from fiber production to fabric finishing all happen in the same firm), knowledge generation and transfer, i.e., know-how, was in-house. In her study that examined small textile factories in Italy, McCaffrey (2013) found that vertical integration is not possible if the knowledge “cannot be secured” and production has to move overseas contracted to compensate for the lack of tacit knowledge, companies have to create smaller chunks based on “codified knowledge”, that is explicit knowledge. This results in a lack of quality and lowers the standards, “becoming less Italian”.

2.4. The benefit of using tacit knowledge in organizations: Knowledge Management

In the apparel product development, the fits session data should be stored and then treated the way the knowledge production was suggested to use by Wethyavivorn and Teerajetgul (2020). The designer and technical designers should share the tacit knowledge so that they could solve the fit issues while taking care of the aesthetic aspects. For example, Wren and Gill (2010) found out that when a designer works in two roles (i.e., a technical designer and a creative designer), they can do a better job in problem-solving due to their “variation of knowledge”.

Although tacit knowledge has been defined as challenging to document and pass on, many researchers have agreed that accumulating and utilizing tacit knowledge as organizational knowledge would enhance an organization's competitiveness (Harlow, 2008; Karin, 2012; Muthuveloo et al., 2017; Nonaka & Takeuchi, 1995; Pavitt, 1991; Sobol & Lei, 1994). "While tacit knowledge is a valuable asset for building up competitiveness, not being able to valorize tacit knowledge can hinder efforts for organizational change" (Goyal & Heine, 2021, p. 642). Pavitt (1991) pointed out that tacit knowledge learned through repetitive product development procedures is one of the key components to keep companies competitive within the industry and suggested that the most effective way of learning tacit skills was through personal contact and discussions. Sobol and Lei (1994) also agreed that accumulated tacit knowledge, which is embedded in an organization's own routines works as a competitive advantage and obtaining the knowledge, involves regular in-person basis contact within certain settings where the knowledge is produced and applied.

To achieve both financial and non-financial profits, organizations need to focus on finding ways to create and transfer knowledge among employees especially, the tacit knowledge (Muthuveloo et al., 2017; Rhodes et al., 2008). Companies should support tacit knowledge management systems along with hardware systems to boost innovative performance (Harlow, 2008). Tacit knowledge management in apparel product development specifically collects sets of solutions to various already detected and unexpected fit issues (Muthuveloo et al., 2017; Rhodes et al., 2008). When similar fit issues reoccur, the knowledge management system and datasets support the fit alteration decisions with evidence. Knowledge management would assist juniors in the fashion field to draw persistent and advanced fit corrections, which turn out to be the company's financial and non-financial profit (Muthuveloo et al., 2017).

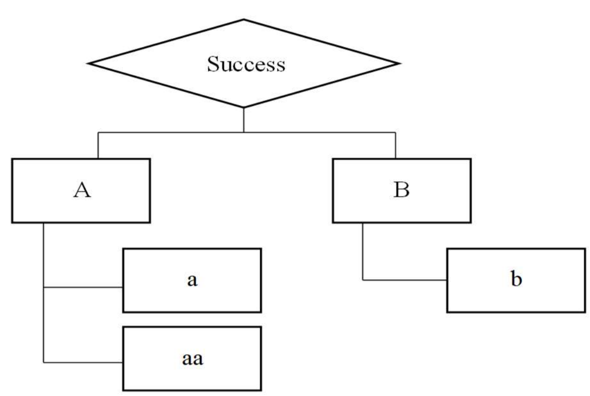
2.5. Methods to elicit tacit knowledge

Tacit knowledge has a degree, which is called the *degree of tacitness* that explains why some tacit knowledge requires significant years of in-person apprenticeship to transfer while some others could be transmitted easily only by following lessons or manuals. Tacit knowledge can be seen as a 'resource' (Barney, 1991; Peteraf, 1993). Tacit knowledge and its management are important because it turns into a company's competitive asset (Goyal & Heine, 2021). When knowledge production and knowledge management are successful, it refers to eliciting personal tacit knowledge, then sharing and developing it within an organization. It allows the organization to spend less amount of time educating employees. Moreover, they experience fewer trials and errors and maintain consistent quality in production/service. It could enhance the profit of the business while easing the entire decision-making process. It helps detect issues, sort solutions, and even contributes to making predictions. Many other fields including nursing and biology incorporated tacit knowledge aspects of their fields and started designing ways to elicit and benefit from the documented knowledge. Even though it is challenging to elicit tacit knowledge, there are several ways to do so as cited in the literature. These methods include the mapping process, observation, and examining problem-solving.

The mapping method (Figure 3), which was proposed by Ambrosini and Bowman (2001), typically starts with semi-structured interviews to better know the participants. The knowledge captured from the interview relies on how well the interviewer asked questions because the tacit skills are in the form of direct interview responses or narratives. This also helps participants feel more comfortable and increase their "confidence in the process". In this method, success can be described as succeeding in an action, such as solving a problem, and the mapping helps understand the reasons behind this success. The questions that are being asked to participants include “how does that happen?”, “What causes that?”, “Who is involved?” and “What influences that?” (Ambrosini & Bowman, 2001). This “digging process” allows for capturing detailed thought processes that led to success. During data collection, it is important to remind the participants that what they believe or think they should be doing must be excluded from their answers and they must focus on what they do instead. A, B, and aa in Figure 3 all refer to their actions that led to successful results which were identified in the interviews. If the participants slow down on their responses or if the number of responses decreases, then the researchers should ask them to tell stories or use metaphors related to the “success factor”. As Ambrosini and Bowman (2001), explained, it is important to write down the factors as actions, such as using verbs and “I” to describe the skills. Therefore, it is not about ‘knowing, or not knowing about’, but about ‘doing’. The process should stop when no more factors can be documented. Observation is a complementary method to the method process. It is based on ethnographic techniques related to participant observation. There are some limitations in performing direct observations in large firms. Researchers may not be able to follow up on every single detail from different departments resulting in not fully interpreting possible queues that led the organizational-level success. (Ambrosini & Bowman, 2001).

Figure 3

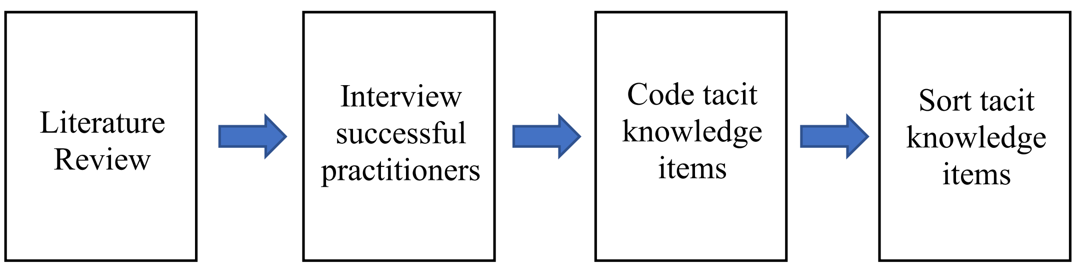
Causal mapping process (Ambrosini & Bowman (2001), p. 823)



In the Sternberg method, Sternberg and researchers (2000) took a qualitative approach to the first stage of building the Tacit Knowledge Inventory (TKI) (Figure 4), which is to identify tacit knowledge. They used a literature review to familiarize themselves with the topic and performed structured interviews with initial individuals, mainly asking them to illustrate the situation and document stories the individuals have. How individuals illustrated their success in addition to their interpretations, such as lessons they have learned over the process, should be transcribed. Because tacit knowledge was written in narratives throughout the process, researchers coded the interview and organized the elicited knowledge into procedural diagrams assigning 'if's and 'then's. The organized datasets could be clustered for later use.

Figure 4

The first stage of building the Tacit Knowledge Inventory (TKI) (Sternberg et al., 2000)



Both methods of eliciting tacit knowledge chose interviews to start collecting data. It was also mentioned using observations to support the process. Thus, this study chose to conduct interviews with important personals and do observations to elicit tacit knowledge in fit sessions.

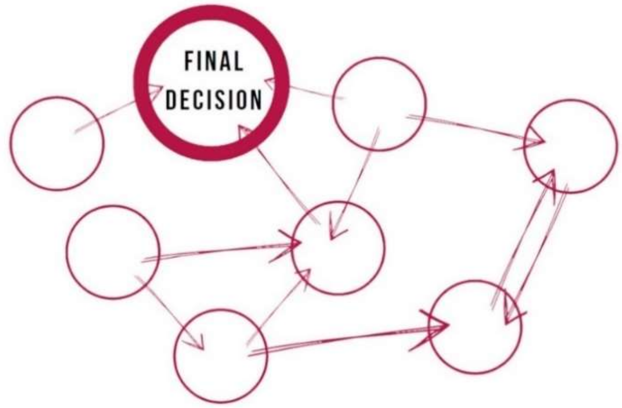
2.6. Theoretical Frameworks

Many players, including designers, merchandisers, and pattern makers, become a part of fit sessions during the apparel product development process. These experts do not share the same level of familiarity with fit evaluations or pattern alterations. It is because they may not be experts in technical design and/or may have spent longer/shorter time in the field related to fit assessment. Despite the knowledge difference among the team members, they share the assessment and meet the agreement when addressing the fit issues and determining where and how to adjust the patterns (Bye & LaBat, 2005). In other words, documenting fit assessments must include the part where the participants discuss and conclude in shared cognition.

The Team Mental Model is an organized knowledge that comes with specific references shared among team members (Klimoski & Mohammed, 1994). Converse et al. (1993) indicated that team effectiveness has improved as team members share a certain amount of knowledge. One of the ways to build the team mental model is to accumulate shared experience as a team (Converse et al., 1993; Cooke et al., 2000). Moreover, Cooke et al. (2000) stated that not only the knowledge from homogeneous teams but also the knowledge from heterogeneous teams, which consist of team members from different disciplines, helps build the team mental model and leads to better team performance. Previous applied cognitive terminologies, which documented the flow of individuals' knowledge, were cognitive maps, categories, or schemas to keep track of knowledge (Klimoski & Mohammed, 1994). Because the team mental model can be related to the terminologies while trying to create explicit knowledge structures (Klimoski & Mohammed, 1994), the model can be applied to document fit assessments. An example of the application of the team mental model in the form of cognitive mapping is presented in Figure 5.

Figure 5

The team mental model through cognitive mapping

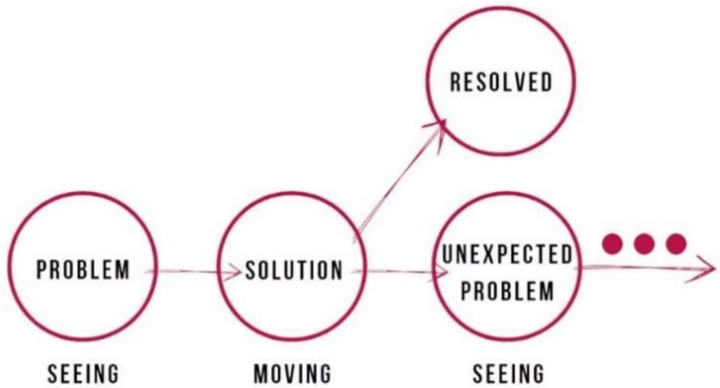


Amongst various cognitive terminologies, a sample framework can be developed to accumulate the data using cognitive maps. The data set would help the experts in the fit testing build the initial team mental model and further improve the team's performance. For the conceptual model, to better understand group decision-making during fit sessions, the current study suggested improving the 'team mental model' by drawing on the 'seeing-moving-seeing' model by Schön and Wiggins (1992) and combining the two models to use as an evaluation tool of group dynamics.

The 'seeing-moving-seeing' model identifies how designers reason and take iterative actions during the active design process (Figure 6). Designers start designing with 'seeing', i.e., judging how the object is and determining which action to take. The second stage is 'moving' the object based on the judgment from the first 'seeing'. However, it is challenging to make the perfect move on the 'moving' because the move would bring unintended consequences as well as intended changes. The third stage is 'seeing' the moved object. It includes judging the previous move and identifying intended/unintended changes. The 'seeing-moving-seeing' repeats until finalizing the design (Schön & Wiggins, 1992).

Figure 6

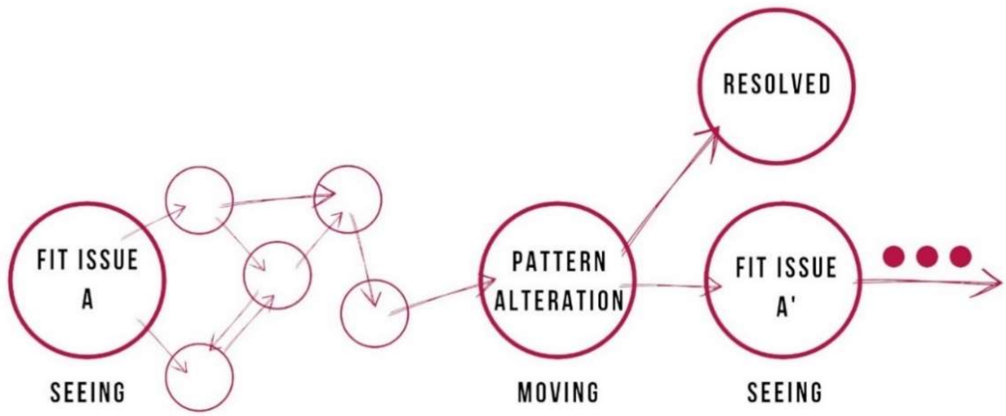
'Seeing-moving-seeing' model (Schön & Wiggins, 1992)



The new model, the improved team mental model, has cognitive maps between 'seeing' and 'moving' stages (Figure 7). Because fit assessments are also a part of designing new garments, the new model could record them by breaking the process into 'seeings' and 'movings'. The new combined model can be used to analyze fit sessions. This model can provide a method for visualizing tacit knowledge among the actor and be expected to generate sets of solutions to various seen or to-be-seen fit issues. This would eventually help reduce the number of trials and errors regarding the fit session. When reviewing the fit comments collected during a fit session, this model can help set priorities among the comments. Especially when many departments or players take part in fit sessions, the priorities among the comments can be simplified by determining what mattered the most in previous similar cases. It could also be beneficial when the new players are recruited. They could reference the dataset to resolve the fit issues efficiently. It includes providing a diverse point of view which helps players perceive the fit issue.

Figure 7

The improved team mental model



In light of the gaps and needs identified in the literature review, the present study was designed to answer the following research questions (RQs):

RQ1: What are the dynamics of decision making in an apparel fit session?

RQ2: What is tacit knowledge of technical designers and fit models and how do they collaborate to solve fit issues?

CHAPTER 3

METHODS

3.1. Research Design

The present study took a qualitative research methods approach in two phases to (1) collect data in the participants' settings and observe participants' behaviors while they are interacting within the settings (Creswell & Creswell, 2018), and (2) gather data from past experiences of one of the fit session actors (i.e., fit models). In the first phase, physical fit sessions, where the designers and fit models were running fit analysis and making comments on adjusting patterns, were observed. Tacit knowledge sharing in fit sessions is a high degree of tacit skills according to the degree of tacitness identified by Chennamaneni and Teng (2011). High degree tacitness refers to 'abstract knowledge' which deciphers complex causations (Blackler, 1995) such as design/fit alterations during the fit sessions. Therefore, tacit knowledge within the process was collected as field notes from observations and voice recordings of the fit sessions. In the second phase, fit model interviews were conducted separately by reaching out to the fit models who work for agencies and for different apparel brands.

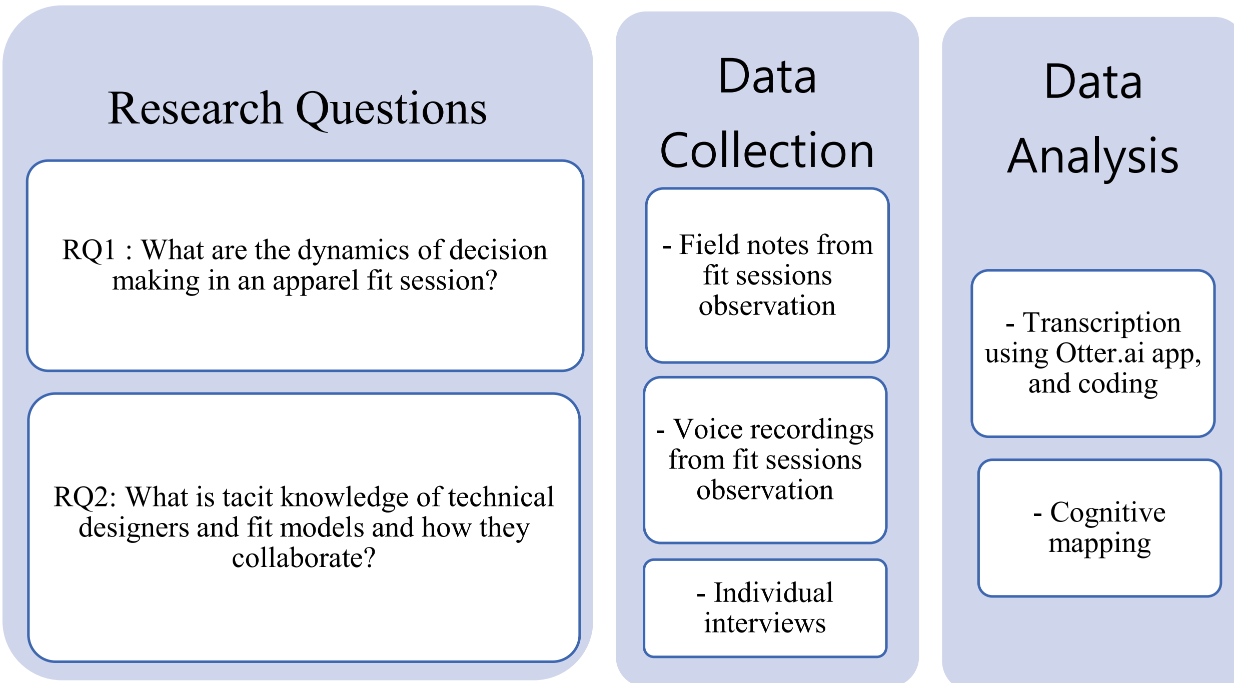
To ensure that tacit knowledge was captured from both technical designers and fit models' perspectives and to have a broader understanding of the dynamics, data was collected from industry fit session meetings as well as fit model interviews. For the industry settings, the case study method was found to be relevant to the purpose of the study which was to find how and why participants engage in activities as well as to understand the real-world case in the related context. Case studies are particularly valuable when the observation aims to capture unique variations from one setting to another (Patton, 1987). The present study met the general features of case studies as (a) the form of research questions referred to 'how' and 'why', (b) events were not controlled, and (c) the research focused on contemporary events (Silverman, 2013; Yin & Campbell, 2018). The study collected multiple sources of data that triangulate each other to get reliable data sets.

The present study used triangulation (e.g., interviews, observations, and questionnaires) to ensure validity. Technical designers and fit models were observed to collect data from different groups although they were situated in the same settings, i.e., the fit sessions. To be specific, fit models, technical designers, and designers, enabled triangulation during the data collection stage. Individual interviews were conducted with fit models and technical designers for aggregate analysis and observed fit sessions for interactive analysis and collectivity analysis (Denzin, 1978). The individual interviews with participants from different apparel departments referred to the aggregate analysis stage in the levels of person analysis (Denzin, 1978). The observations of fit sessions referred to the interactive analysis to mainly follow the interactions in the natural field settings while analyzing the different role positions of participants in the fit sessions referred to collectivity analysis (Denzin, 1978). Research questions in the two phases of the study were presented in Figure 8.

The recruitment of the participants and accessing fit sessions proved to be very challenging from the start. More than twenty apparel companies in the U.S. were contacted, however, every attempt to attend fit sessions and collect 2D garment pattern modification examples was rejected due to the confidentiality of the process- except for only one apparel company. Even though the companies' technical designers initially expressed interest, when legal teams were involved in the communication the attempts to collaborate with the companies failed. When communicating with the legal teams, a non-disclosure agreement upon publishing was brought up as well. Some companies wanted to limit the data being collected during the study to their old or current collections, while some of them did not want to allow recording voices or taking photos during fit sessions.

Figure 8

Research questions with data collection and data analysis methods



3.2. Participants

Participants in this study were apparel technical designers, designers, and fit models, who were older than 18 years, and could communicate in English effectively. Companies were contacted for their approval to conduct observations and interviews at their facilities. Starting from the initial contacts in the industry, additional research participants were recruited by snowball sampling, contacting more insiders connected to the previous interview participants after their interviews (Patton, 1990). Purposeful sampling was used to collect data from information-rich companies and participants which enabled in-depth research (Patton, 2002).

3.3. Data Collection

Fit session observations

On the fit session observation day, the room setting was sketched to indicate the locations where the fit model stands, where the technical designers were, and other things in the room. Props in the changing room as well were documented including three-way full-sized mirrors and clothing racks with samples to be worn in the fit session. Voice recorders were used to capture the conversations. The purpose of the study was explained to the fit session participants before the session and consent forms were signed. During the observations, field notes were taken for triangulation. According to the roles that participants were taking in the fit session, the field notes were written in different colors for further identification. Observer comments were added in field notes. Immediately after the observation session, the researcher uploaded the voice recordings to otter.ai for transcribing. The journal entry to note the full description of the observations was made according to the format as shown in Appendix III. Because the company did not allow pictures to be taken during the observation, sketches pertaining to the fit issue and solution were created.

Fit session interviews

As a part of fit session observation, interviews with fit session participants were conducted. During short breaks within the fit session, unstructured interviews asking open-end questions were conducted to verify comments made during the fit session and to confirm how participants suggested solutions. Voice recorders were used to capture the interviews. The recorded files were uploaded to otter.ai for transcribing verbatim.

Fit model interviews

Fit models were recruited by using the purposeful snowball sampling method. Technical designers in the researcher's personal contact list were contacted to recruit fit models for the second phase of interviews. The fit models referred to by the researcher's personal contact were the first interview participants in the second phase of the research. More fit models were recruited by reaching out to the initial fit models' contacts following the purposeful snowball sampling.

The interviews were conducted via Zoom calls for the participants' convenience. Participant consent forms were explained and signed before the interviews started. Interviews were voice recorded and the researcher took a field note according to the interview protocol (Appendix II). The semi-structured interview questions included previous work experience, personal job description as a fit model, and how they were trained to perform the job descriptions. Besides the researchers' observation on site within the fitting environment, how fit models describe their professions based on their years of experience was documented through the individual interviews to add an insider's perspective on the research questions. Some of the open-ended questions were added to include details regarding tacit knowledge. Some follow-up questions were asked to elaborate on their previous fit sessions to understand the context. The interviews were recorded with a voice recorder and also uploaded to otter.ai immediately following the interview.

In addition to the fit model interviews, one technical designer was recruited after the data analysis of the study to ensure trustworthiness of the findings. It was a semi-structured individual interview to get detailed explanation about fit sessions and their relationship with fit session participants on technical designer's point of view. The interview was conducted via Zoom and the participant consent form was explained and signed before the interview. The conversation was voice recorded and notes were taken. The semi-structured interview questions included previous work experience, and how technical designer, designer, and fit models interact in fit sessions. The interviews were recorded with a voice recorder and uploaded to otter.ai immediately following the interview.

3.4. Data Analysis

Fit session observations

Observation data were analyzed in two ways, (1) documenting apparel product development-related tacit knowledge found in the fit sessions and (2) the decision-making process regarding the type of issues presented in the fit sessions. When voice recordings of the fit sessions were uploaded to and transcribed in Otter.ai. The conversations were listened to again to correct the typos or other mis-captured parts. The transcribed file was coded manually. To document tacit knowledge in fit sessions, the voice recording has gone through the first cycle coding (i.e., In vivo Coding). Throughout the first cycle coding, ‘fit issues’ and ‘following solutions’ were determined to build a basic structure for causal maps. Another set of coding (i.e., Descriptive Coding) with the observation data was conducted to follow the decision-making process in fit sessions and added to the causal map as well. The codes were grouped based on the causes in the data. In addition to the descriptive notes from the fit session observation, reflective notes were taken as well. The observer’s comments (OC) included the subjective memos summarizing diverse topics covered in the fit session besides merely editing 2D patterns of garments.

Once the data was gathered, the improved team mental model was used to better analyze the decision-making dynamics and elicit tacit knowledge of the actors. In the diagrams, ‘visual clues’ were used referred to visual misfits found on garments that fit models were wearing.

‘Action items’ were narrative actions that needed to be taken to resolve fit issues. ‘Pattern alterations’ were specific 2D pattern change solutions to resolve fit issues. Following the creation of the diagrams by using the research model, tables were created to include ‘the level of visual clues’ which indicated the priority of the visual clues. Level 1 visual clues were considered to have the top priorities because they were causing more than one other visual misfits on garments. Correcting Level 1 visual clues included adjusting irrelevant 2D patterns where the visual clues were not present. Although 2D pattern alterations were made in the area where visual misfits were not apparent, it could ultimately correct Level 1 visual clues. It also was visualized in following figures by the multiple arrows each Level 1 visual clues started which indicated causal relationships between elements. Level 2 visual clues were causes of one other visual misfit and could be fixed by adjusting the area where the visual clues were found. Level 3 visual clues showed visual misfits, but it had been derived from other areas and did not need to alter 2D patterns.

In the diagrams drawn based on the improved team mental model theoretical framework, major fit issues caught from the garment ‘seeing’ and the final pattern 'moving’ decisions after discussions were colored black. Detailed visual clues identified among fit session participants were red. Verbal comments and tacit knowledge of fit models were colored blue, while technical designers’ comments were green, and designers’ comments were yellow. Other additional information or restrictions regarding garment productions were colored orange. Causal relationships were marked with arrows and correlations were drawn in plain lines.

Fit session interviews

The main reason for having individual interviews with fit session participants was to enhance the understanding gained from the fit session observations and to complete the casual maps which had some missing information due to innate implicit features of tacit knowledge. The voice recordings of the interviews were uploaded to and transcribed verbatim in Otter.ai, and the transcript was coded in manually.

The first cycle coding was done with Descriptive Coding. The codes from the first cycle coding were placed to fill the gap between ‘fit issues’ and ‘following solutions’ of the causal maps drawn from the fit session observation coding. The connections between the actions taken in the fit sessions and the decision-making thought processes were illustrated. The findings from the observation were summarized and shared with the fit session attendees for their further comments and to achieve the trustworthiness of the results.

Fit model interviews

Fit model interviews were transcribed verbatim in Otter.ai, and the transcribed file was coded in Microsoft Excel. In Vivo Coding was used for the first cycle coding. The first cycle coding was followed by Descriptive Coding. The semi-structured interview questions were designed to get specific information including ‘fit session interactions’, ‘fit model’s tacit knowledge’, or ‘fit model’s knowledge transfer’. Descriptive Coding was selected to understand the main themes of the fit model’s tacit knowledge and organize them as it has not been studied thoroughly (Saldaña, 2016). Codes such as ‘temporary’ came from fit models’ quotes like “if you have your period, if you ate hot dog” (Ava) and “feeling a little full today” (Olivia) which indicated that they sense temporary changes in their bodies. On the other hand, ‘permanent’ were found from quotes like “naturally one of my calf muscles is smaller” (Ava) which showed that she knew her exact body specs and may not easily change. It referred to her original features of her body.

CHAPTER 4

RESULTS

4.1. Results from the Physical Fit Session Observation and Fit Session Interviews

The observations took place at a small-scale U.S.-based apparel company, which is located on the East Coast and manufacturers men's and women's business wear. The fit session observed was a second-round fit session, which took four hours and included seven tops and six bottoms (e.g., jackets, shirts, shorts, slacks, and joggers) that would be a part of the company's Spring 2023 and Fall 2023 collection. Fit models were changing in the restroom which had above-hip length mirrors inside. They also had a full-length mirror right next to the fit testing room.

Participants

Two male designers and one female designer from the same company, one female technical designer, who was brought as a consultant with a vast patternmaking experience in the industry, and two fit models (one men and one woman) participated in the fit session. Both fit models, for whom the pseudonyms Liam and Mia were used henceforth for quotes, wore size medium garments. Both models had been working with the company for about two years. Two designers had been in the fashion industry as designers for over 15 years and one designer worked for about two years as a fashion designer.

Table 1

Fit session observation participants

Fit session participants pseudonym	Sex	Occupation	Years of industry experience
Kai	M	Designer	25+ years
Ivy	F	Designer	2 years
Jayden	M	Designer	15+ years
Nova	F	Technical Designer	15+ years
Mia	F	Fit model	5 years
Liam	M	Fit model	2 years

Observation findings from fitting Garment 1

The first garment was a pair of poplin shorts that hit the mid-thigh and was a part of the menswear collection. It had two pockets on the front and two pockets on the back. The design of the garment was basic with belt loops around the waist. It was already out in the market for sale but tested in the fit session again to meet the better fit. Therefore, the adjustment was not drastic but a slight change. The shorts were fit-tested on the male fit model. He was an athletic type of fit model with bigger thighs and shorter inseams than average. He stood still, did walking lunges, and did squats during the fit testing of the garment. He was asked to stand still when visual cues were collected by the technical design team members. The fit of the shorts had been tested with the matching t-shirt while the t-shirt was tucked into the shorts. During the process, one of the designers took photos of the visual clues they found and took notes of how and where the alteration should happen with brief 2D pattern drawings.

The fit model did not make any comments on the shorts until he was asked how he felt about the fit around the crotch area. The technical designer and designers first shared their opinions about the visual clues, which indicated misfit, they could get from the garment. The design team collected the clues through a repetitive conversation of one referring a clue to the team and the rest confirming it. The visual clues confirmed through the conversation were:

1. Inseams dragging forward
2. Uneven hem comparing front and back
3. Horizontal dragging lines on hips
4. Horizontal dragging lines on the side seams at the mid-hip
5. Opening front pockets

The team agreed on the idea that visual clues 3, 4, and 5 all indicated the fit issues around the hip area, and because they were occurring at the same horizontal level, the team concluded that they were all connected. Then three action items were settled:

a. Align inseam
b. Even hem
c. Remove horizontal drag lines around the hip area

However, each team member suggested different ways to meet the action items. The team realized that when the action item 'a' was met, the item 'b' would be naturally met. Therefore, they eventually considered 'a' and 'b' as a set and 'c' was considered as a separate item. The suggested pattern alterations from designers were:

i. Edit front panels' inseams to meet 'a'
ii. Add extra inches on side seams around the hip to meet 'c'

On the other hand, the experienced technical designer believed that both 'a' and 'b' could automatically be met when 'c' was satisfied. She thought that visual clues 1 to 5 were all connected and the misfit around the hip (detected from visual clues 3, 4, and 5) was the main reason that brought other visual clues into the equation. Three other clues she brought up to suggest her pattern alterations were: that similar horizontal dragging lines had been found in women's wear fittings and different men's wear designs, the garment had a correct spec when laid flat and measured before the fit session, and the fit model commented crotch point was in the right place. She got verbal confirmation by asking the fit model to make sure the shorts were sitting in the right place on the body. Instead of editing inseams separately, she suggested some ways to make room around the hip:

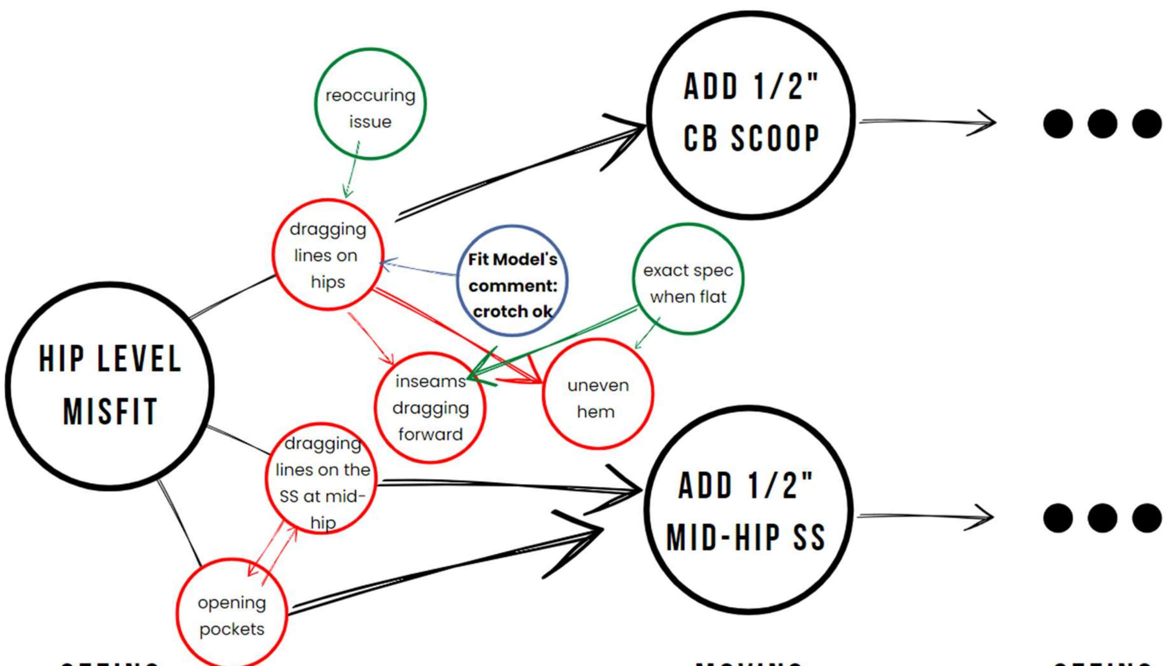
i. Add ½" to the apex of the center back scoop

ii. Add ½" on side seams at the mid-hip level

Upon further thinking, the technical designer persuaded the designers by explaining that the extra room around the hip area can be created by adding ease to the center front and the side seam, and it would bring the dragging inseam back to the correct alignment. Moreover, this could even fix the uneven hem as inseams aligned perpendicular from the ground. Each team member agreed on the solution to the pattern adjustment and moved on. The entire decision making process was organized in Figure 9 based on the improved team mental model theoretical framework.

Figure 9

Observed fit issues and suggested pattern changes for Garment 1



Major fit issues from 'seeing' and final pattern 'moving'
Fit model's tacit knowledge
Visual clues
Technical designer's tacit knowledge

In Figure 9, which was drawn based on the improved team mental model theoretical framework, major fit issues caught from the garment ‘seeing’ and the final pattern 'moving’ decisions after discussions were colored black. Detailed visual clues identified among fit session participants were red. Verbal comments and tacit knowledge were colored blue for fit models and green for technical designers. Causal relationships were marked with arrows.

In the diagrams, arrows indicated relationships between comments as well as visual clues. One initial visual clue was a cause of several other visual clues. The initial visual clue that was found to have had affected more than one visual clues was highlighted in Figure 10. The initial visual clue, ‘dragging lines on hips’, was affecting two other visual clues; therefore, it was classified as a ‘Level 1’ visual clue. The rest visual clues were only affecting one other visual clue, which meant they were minor issues and were classified ‘Level 2’ visual clues.

Figure 10

Initial visual clues

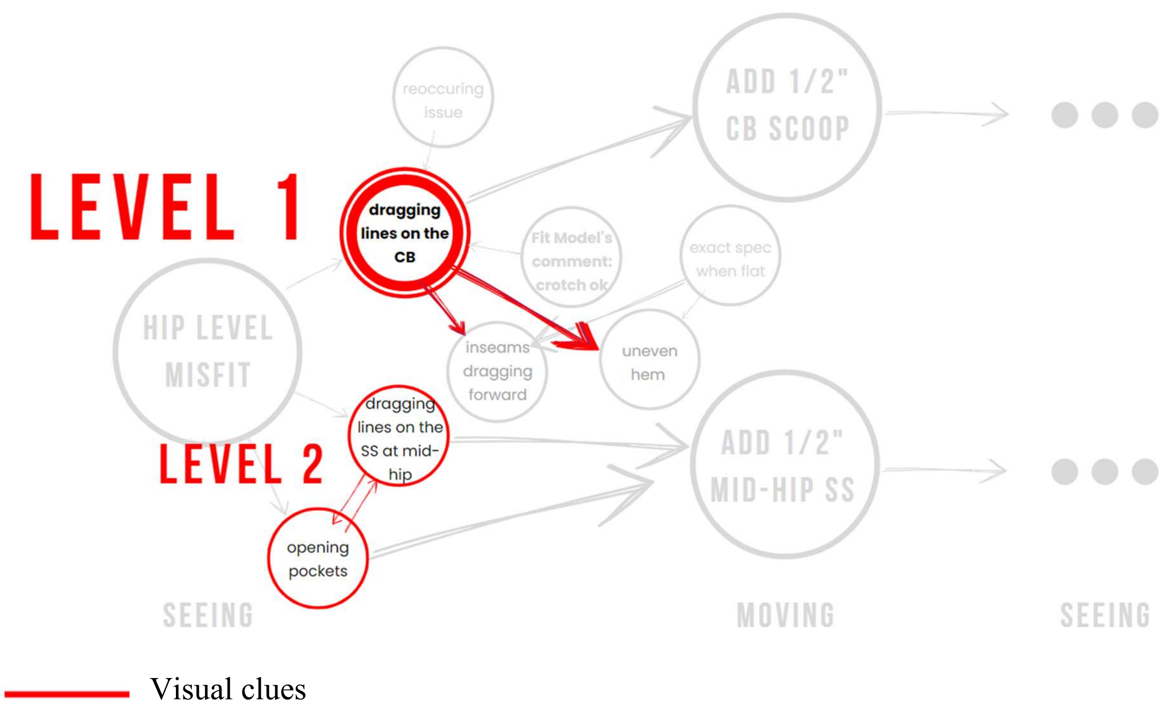


Table 2 shows the levels of each visual clue identified from the Garment 1 and lists them based on the highest (1) to the lowest (3) priority.

Table 2

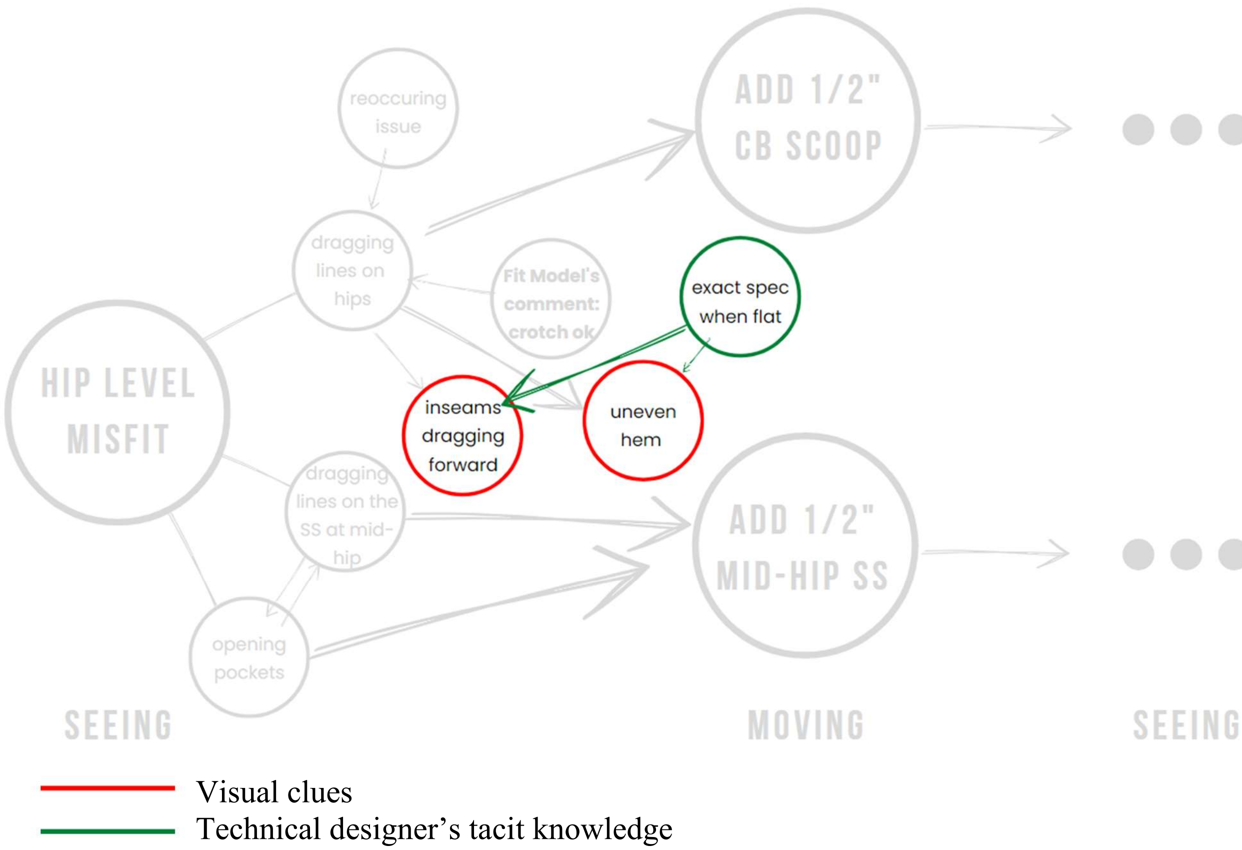
Levels of visual clues in Garment 1

Level by Priority	Visual Clues
Level 1	• Dragging lines on hips
Level 2	• Dragging lines on the side seams at mid-hip • Opening pockets
Level 3	• Inseams dragging forward • Uneven hem

One of three clues that the technical designers included in the discussion was that the garment had a correct spec when laid flat. The clue was highlighted in Figure 11. The clue she included affected visual clues, 'inseams dragging forward' and 'uneven hem'. It verified that those visual clues of misfit were not derived from manufacturing failures but created during the interaction with 3D human body. It also helped determining two visual clues, 'inseams dragging forward' and 'uneven hem', did not need direct literal pattern alterations. They were classified as 'Level 3' fit issues as they were not directly connected to the 'Moving' decisions which were 2D pattern alterations. Rather, they were the indicators of the 'Level 1' fit issue.

Figure 11

Garment specs when laid flat



Observation findings from fitting Garment 2

The second garment was a button-down collar shirt. It was a part of the company's menswear collection. It had two small buttons under the collar on the front bodice which allowed the collar to be buttoned. The shirt was fit tested on the male fit model. It was worn alone on the torso with matching tapered pants. The design of the shirt was not new, but the sample was made from new fabric, which was a lighter in weight for the season. The fit model stood still while visual cues were collected by the technical design team members. During the process, one of the designers took photos of the visual clues they found and took notes of how and where the alteration should happen with brief 2D pattern drawings.

The fit model did not make any comments on the shirt until he was asked how he felt about the neck. Designers first shared their opinions about the design of the collar and shared the visual clues, which they could get from the garment. The design team collected the clues through a repetitive conversation of one referring a clue to the team and the rest confirming it. The visual clues confirmed through the conversation were:

1. Button-down buttons were dragging the collar down
2. The collar was too stiff
3. The collar was too short when unbuttoned

The team agreed that the collar needed to be altered design-wise. The fit model was asked whether the collar was choking or bothered his neck on the back. The tactile feedback from the model was that the collar had no functional issues but was not aesthetically pleasing. Then three action items were settled:

a. Adjust the collar to be less stiff
b. Move button-down buttons
c. Correct the collar points

The team members agreed to change the interfacing, which is an additional layer of nonwoven fabric that is fused to patterns to provide support/ stiffness, of the collar for item ‘a’. It was followed by an additional tactile clue that the cuffs of the shirt were way too stiffer than expected. Therefore, one of the sample adjustments was confirmed to change the entire interfacing of the shirt.

i. Change the entire interfacing of the shirt to a lighter one to meet

Pattern alteration for the action items ‘b’ and ‘c’ was solely on the designers. The decision was made by one of the designers while moving the collar points to determine where to move and eyeballing the place where the new button-down buttons should be. Action items ‘b’ and ‘c’ were found to be interrelated as the visual clue should be the misfit around the point of the collar. The suggested pattern alterations were as follows:

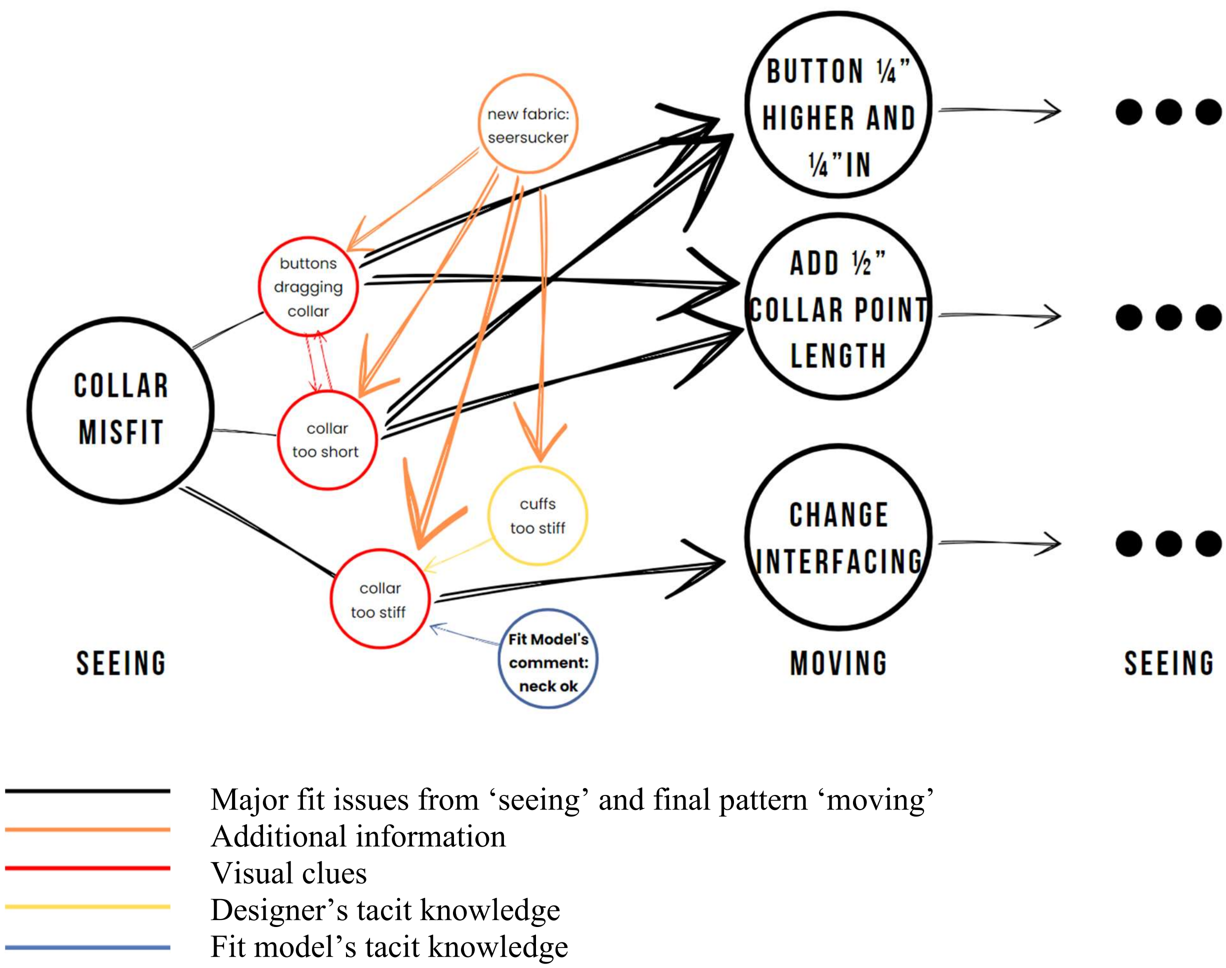
ii. Move the button-down button ¼” higher and ¼”in

iii. Add ½” to the collar point length

The team members met the agreement with the suggestions simultaneously when they saw him placing the collar in the right place. The entire process of fit evaluation and confirming alterations are visualized in Figure 12.

Figure 12

Observed fit issues and suggested pattern changes for Garment 2



In Figure 12 drawn based on the improved team mental model theoretical framework, major fit issues caught from the garment 'seeing' and the final pattern 'moving' decisions after discussions were colored black. Detailed visual clues identified among fit session participants were red. Verbal comments and tacit knowledge were colored blue for fit models and yellow for designers. Other additional information or restrictions regarding garment productions were colored orange.

Garment 2 did not have any 'Level 1' fit issue, but it had two 'Level 2' fit issues and one 'Level 3' fit issue (Table 3). The visual clue 'collar too stiff' were under 'Level 3' because it was not followed by '2D pattern alteration Moving' but changing materials on the production level.

Table 3

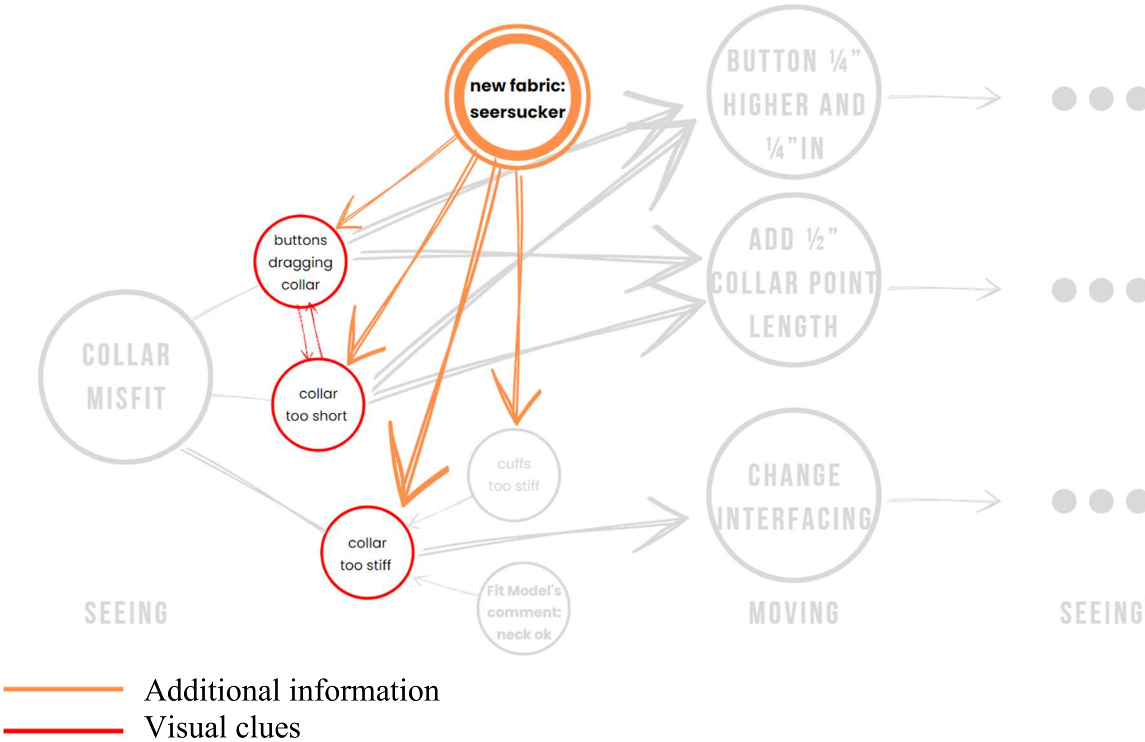
Levels of visual clues in Garment 2

Level by Priority	Visual Clues
Level 2	• Buttons dragging collar • Collar too short
Level 3	• Collar too stiff

The new fabric, which technical team member had no prior knowledge, was the main cause of the visual clues (misfits). To be specific, how the new fabric responded to the existing interfacing was unknown until the team produced the sample garment. The element affected three visual clues and generated a misfit of cuffs as well (Figure 13).

Figure 13

New fabric that affected garment fit



Observation findings from fitting Garment 3

The third garment was a basic shirt, which was a new design for the company's womenswear collection in the upcoming season. It had two buttons at the end of the sleeve, one on the cuff and the other one on the cuff placket. During the process, one of the designers took photos of the visual clues they found and took notes of how and where the alteration should happen with brief 2D pattern drawings.

The shirt was fit tested on a female fit model, who had long skinny arms. The shirt was worn alone on the torso with matching tapered pants. The fit model moved her arms making hugging positions. She also tried lifting her arms up. The fit testing started with her comments on comfort that the sleeve was too narrow, and the cuffs opening did not allow her to lift her arms.

The fit model stood still while visual clues were collected by the technical design team members. She commented, “I have skinny arms, but I can’t move my arms. It gets stuck here and won’t move. Like right here, and that’s it” (Mia). However, the designers were satisfied with the narrow-tapered sleeve design aesthetic-wise. The collected visual clue was as follows:

1. Tensions at back shoulders when moved

Designer’s comments on design were as follows:

2. Sleeve silhouette was perfect
3. Sleeve length was perfect

Additional visual information was as follows:

4. Back shoulder area fitted well

The action item was as follows:

a. Add mobility to the sleeve

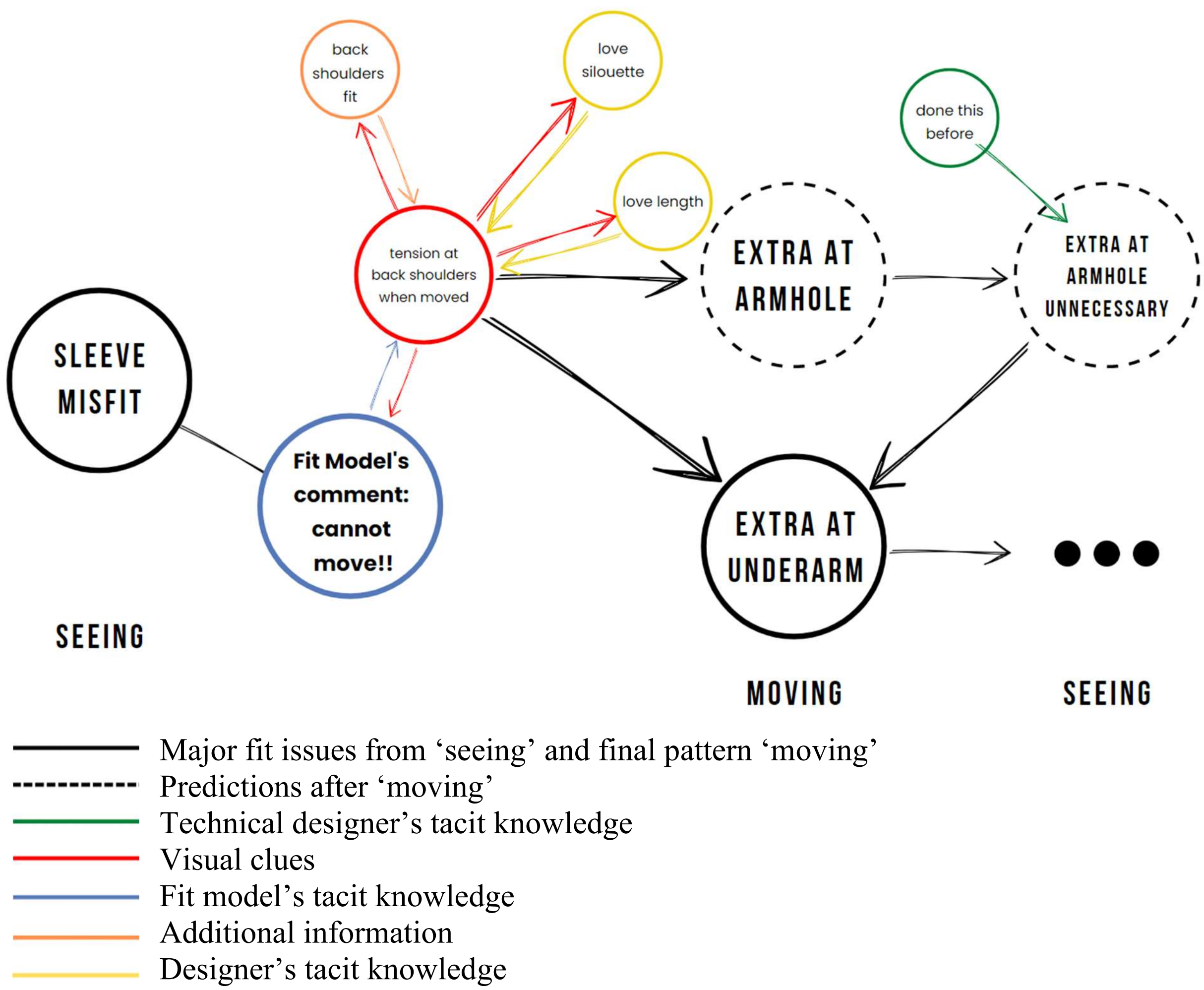
To meet the item, the following pattern alterations were suggested:

i. Add an extra amount at the underarm area on the sleeves
ii. Adjust the armhole accordingly

However, the team members agreed to take only the first pattern alteration and rejected the second one. One of the designers asked the experienced technical designer how they should alter the armhole and the technical designer answered that based on her previous experience they could reject the second suggestion. She had made the same alteration with the last season’s jacket during a previous fit session, and it turned out that they did not need to fix the armhole. She commented while pointing at a jacket on the mannequin in the room saying, “we don’t need to. It was okay on that jacket, remember?” Figure 14 shows the decision-making process of resolving fit issues of Garment 3. The improved team mental model was developed to document ‘movings’ which were actually performed. However, in order to follow the thought processes and record the decision-making process in detail, the predictions that affected the final 2D pattern alterations were also visualized in dotted lines in Figure 14.

Figure 14

Observed fit issues and suggested pattern changes for Garment 3



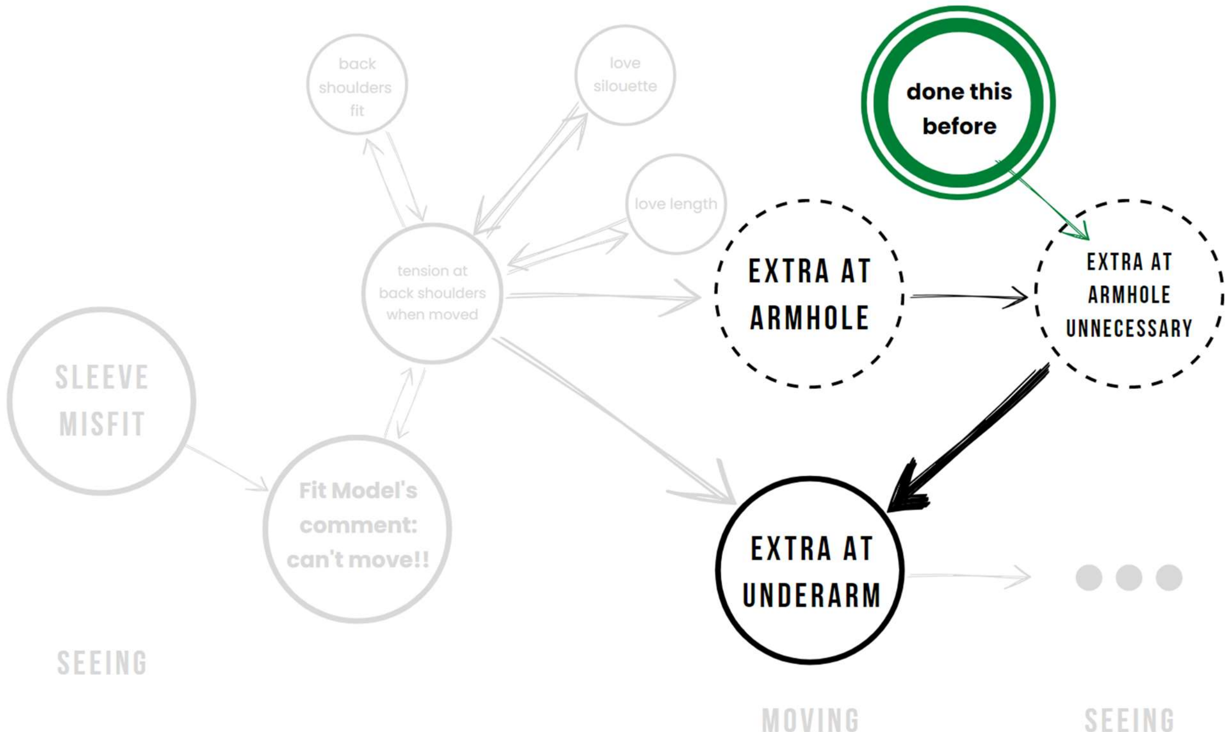
In Figure 14, which was drawn based on the improved team mental model, major fit issues caught from the garment ‘seeing’ and the final pattern 'moving’ decisions after discussions were colored black. The predictions of ‘moving’ and following ‘seeing’ were in dotted black. Detailed visual clues identified among fit session participants were red. Verbal comments and tacit knowledge were colored blue for fit models, green for technical designers, and yellow for designers.

The visual clue found in the Garment 3 was a ‘Level 1’ visual clue, which needed pattern alterations. The visual clues of misfit only appeared when the fit model was moving, and the visual clue was interrelated with the silhouette as well as the length of the sleeves. Although the visual clue indicated ‘tensions at back shoulders when moved’, neither the back shoulder area nor the back panel had visual clues of misfit when the fit model was in standing pose with her arms down.

Along with predictions illustrated in dotted lines, there were reasons why certain ‘movings’ were rejected. In Garment 3, the previous experience of technical designer was additional information that affected ‘moving’. Figure 15 stresses one of the reasons, ‘done this before’, which helped technical team members to reject ‘extra at armhole’.

Figure 15

Previous experience that helped the prediction



Major fit issues from 'seeing' and final pattern 'moving'
Predictions after 'moving'
Technical designer's tacit knowledge

Observation findings from fitting Garment 4

The fourth garment was a stretchy, tapered full-length jogger that had a thin long gusset piece on the inseam and was a part of the company's menswear collection. It had drawstrings and an elastic waistband for wearers' comfort. The jogger was designed to perform as business casual and activewear. The inseam length of the garment was 30". The fit of the jogger was tested with the matching dress shirt while the shirt was tucked into the jogger. The male fit model stood still, did walking lunges, and did squats during the fit testing of the garment. He was asked to stand still when visual cues were collected by the technical design team members.

The fit model did not make any comment on the jogger at all. A few visual clues of misfit were found during the fit testing, but the designers decided to change the design of the garment. The pattern blocks had to be altered. First, all team members agreed to remove the horizontal design cut they had on the calves. The bottom hem block was cutting the gusset design-wise. Therefore, removing the block brought an action item:

a. Alter gusset design

Designers suggested extending the gusset pattern block:

i. Extend the gusset all the way to the hem

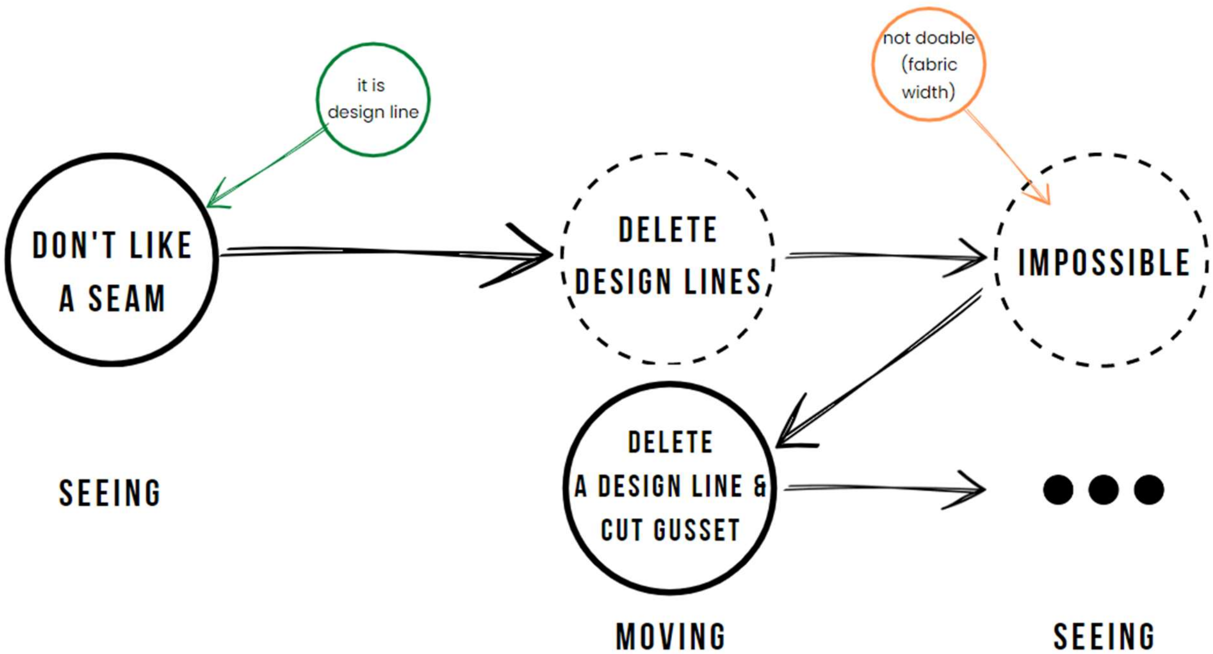
However, one of the designers commented that constructing the gusset during manufacturing would not be easy if it was extended. The inseam length of the sample garment was 30 inches, and the gusset piece should be about 60 inches long. After a few rounds of conversation over the gusset design, the following pattern alterations were confirmed:

ii. Keep the design line on the calf level only in the gusset piece

Although there were no fit issues in the jogger, the gusset piece needed pattern alterations regarding production viability. Figure 15 shows the decision-making process to confirm design alterations of Garment 4.

Figure 16

Observed fit issues and suggested pattern changes for Garment 4



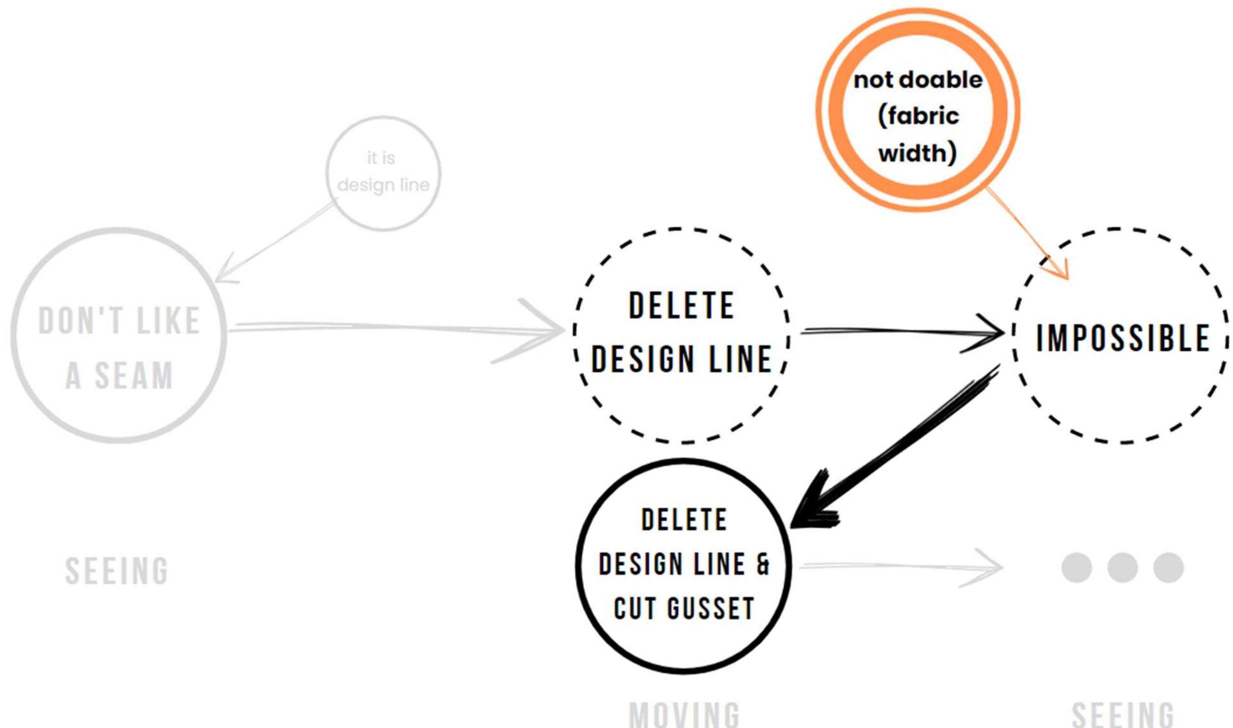
Major fit issues from 'seeing' and final pattern 'moving'
Predictions after 'moving'
Additional information
Technical designer's tacit knowledge

In Figure 16, major fit issues caught from the garment 'seeing' and the final pattern 'moving' decisions after discussions were colored black while the predictions were in dotted lines. Technical designer's tacit knowledge was in green. Other additional information or restrictions regarding garment productions were colored orange.

During the seeing-moving-seeing of pattern alterations based on designer's aesthetic intentions, new comment related to manufacturing capability, 'not doable (fabric width)', helped technical team members to reject 'delete design lines' and develop an alternative 'moving' idea (Figure 17).

Figure 17

Manufacturing capability that supported pattern alterations



Major fit issues from 'seeing' and final pattern 'moving'
Predictions after 'moving'
Additional information

Topics discussed in fit sessions

Through the first cycle of Descriptive Coding, by using the descriptive and reflective notes, three themes were identified regarding the fit session observation: 'fit alterations', 'consistent grading', and 'viable production plans'. These three themes were the major topics discussed and confirmed in the fit session. Fit alterations were analyzed in detail in the previous section. Following OCs helped the researchers to identify 'constant grading' as one of the themes in fit sessions. Codes identified from the transcript included 'one size up', 'ratio', 'half size samples'.

> *OC: The amount (i.e., ½" or 1") is determined based on visual clues but also gradings. If the sample measurements are changed, the same area of graded patterns should be*

altered as well. Adding more than 'one size up' does not seem to be preferred. The grading amount between sizes works as a guide.

OC: Keeping the same garment shapes in size 28 and size 44 is tricky. Do you need to keep the ratio of the knee circumference over the leg opening or do they have to be graded based on mere numbers? Who on earth could imagine what it looks like just by seeing the size chart with over 120 measurements?

The theme, 'viable production plans', was also identified from the following OCs. Some codes identified from the voice recording were 'off the spec', 'fabric width', and 'interesting fabric'.

OC: Is it doable at the mass production level? I have never thought of considering fabric width when designing a garment.

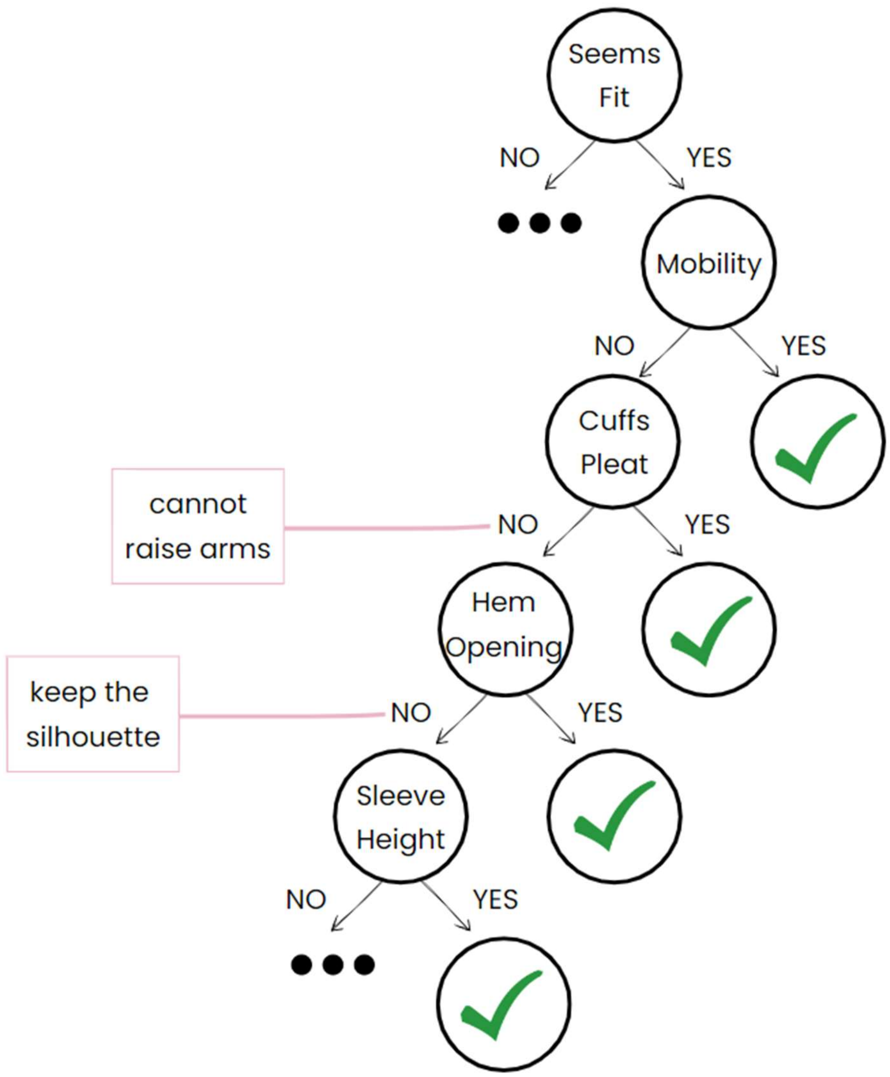
OC: How to minimize customer's inconvenience from shrunken seersucker shirt after washing? They added prewash but are still expecting some changes. Can I have a shrinkage database of each fabric and design stable manufacturing stages with the information incorporated?

Technical designer's tacit knowledge

In addition, through the first cycle coding, Descriptive Coding, of fit session observations and fit session interviews, the technical designer's thought processes in fit alterations were organized by means of an if-then syntax tree (Figure 18). From the observation, it was found that the final 2D pattern alteration of Garment 3 was to add an extra ease amount at the underarm area of the sleeves to adjust the sleeve cap height. When the thought processes of the decision were followed, it was found that the technical designer had considered multiple solutions to fix the mobility issue of the shirt. Figure 18 illustrates the thought processes of how the technical designer confirmed the fit alteration starting from the observed issue which was ‘limited mobility although the sleeves seemed fit’. The mobility of the sleeves could be met by multiple 2D pattern alterations, but each option was rejected for reasons such as the fit model’s comment that “it gets stuck here" (Mia) and the designer’s preference, “I love the skinny sleeves, looks great” (Kai). Those conditions and restrictions led to the final decision.

Figure 18

The technical designer’s tacit knowledge of pattern alterations



Fit models could have witnessed that technical designers suggest multiple pattern alteration ways to resolve one fit issue because they work closely with multiple technical designers. One of the individual fit model interview participants, Ava, elaborated on the pattern alteration skill level of technical designers as the following:

> *think of it as a math problem. Sometimes you can arrive at the correct answer with a slightly different methodology. So, meaning, there's more than one way to correct the fit of a garment. There are different ways that you can bounce it, you either do it from this side, or from that side. And there are so many tricks…are you gonna go for the easiest or the most appropriate one? Like, if you're working with a junior tech designer, you might just give them the easiest solution like, oh, I think you should open it up a quarter inch here and adjust the slope. But if you're working with like a ***, then you might get a little bit more into it and fix it perfectly appropriately. And then you're both like super satisfied. But you still can end up with the correct answer*.

4.2. Results from fit model interviews

Participants

Seven fit models, five women and two men, were recruited for fit model individual interviews (Table 4). Six of them were size medium fit models while one of them was a plus-size model. Four of them had more than 14 years of professional experience as fit models while two of them have been in the industry for less than three years. The clothing brands they were covering were various including athletic sports apparel, lingerie, luxury dresses, and formal business wears. None of the fit models had fashion-related education before they started working as fit models. Only one of them got a brief informal overview of the job professions from formal fit models. Most of the technical terms that they understood and used during their work had been gained from their work experience. Four fit models out of seven were full-time fit models who did not have other occupations. Other three fit models were part-time fit models who had other occupations with rather flexible schedules such as actors/actresses or estheticians.

Table 4

Participants of fit model individual interviews

Fit model pseudonym	Sex	Size	Years of industry experience	Full-time /part-time	Recruited via/ at
Olivia	F	Medium	15+ years	Full-time	Personal contact
Emma	F	Plus	2 years	Part-time	Personal contact
Ava	F	Medium	15+ years	Full-time	Snowball sampling
Oliver	M	Medium	14 years	Full-time	Personal contact
Luna	F	Medium	14 years	Full-time	Snowball sampling
Mia	F	Medium	5 years	Part-time	Company observation session
Liam	M	Medium	2 years	Part-time	Company observation session

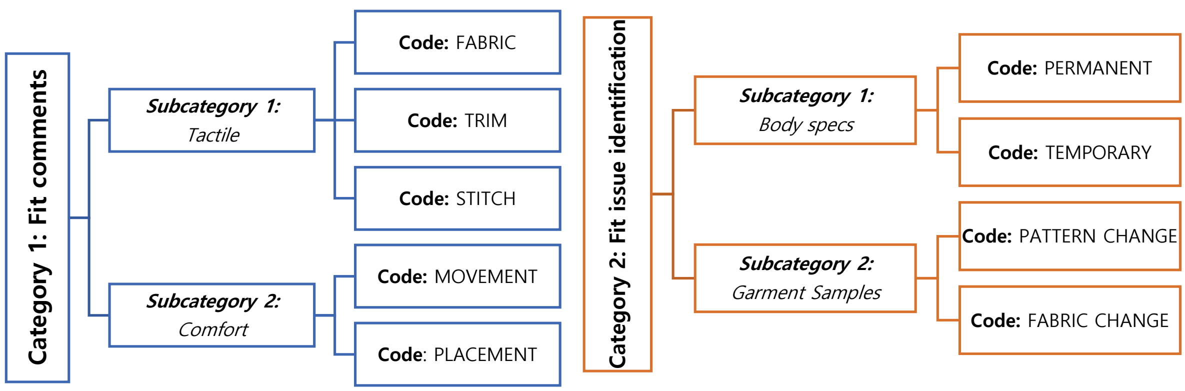
How fit models perform their profession

Several codes were found after conducting the first Descriptive Coding and the second cycle of Pattern Coding. The codes were organized into two categories and subcategories. The pattern coding helped reveal two main categories, which were labeled regarding tacit knowledge of fit models. The overall hierarchical tree of codes was shown in Figure 13. The first category was

'Fit comments.' It had two subcategories, i.e., 'tactile' and 'comfort', under which codes such as 'fabric', 'stitch', and 'trim', 'placement' and 'movement' were identified. The second category was 'Fit issue identification", which had two subcategories, 'Body specs' and 'Garment samples'. The codes identified for 'Body Specs' included 'permanent' and 'temporary', and 'Garment samples' had 'pattern change' and 'fabric change' for the codes.

Figure 19

The overall hierarchical tree of codes



Fit models explained that most of the comments they made during fit sessions were related to their tactile experience. For example, "fabric too itchy" (Luna) and "tension is too tight on the stitches and rolling in" (Olivia) were some of the comments that the fit models elaborated on during the interviews. It also included precise comments such as "scratch [her] everyplace [she] feels…they need to be covered with the binding" (Olivia), which suggested how to fix the issue based on their tacit knowledge. The second subcategory *Comfort* was germane to the wear comfort as fit models were the first customers who were trying on the garment. Whether the garment stayed in the right place when worn and whether it allowed the wearer to move freely during the movement were commented on as fit feedback. The fit models also elaborated some examples which were "do a hug test sort of thing" (Emma) to indicate the mobility of a jacket and armhole area. Additional placement comments included in the subcategory were "pockets work great, location and size" (Liam) while the fit model simulated putting his cell phone into the pocket to explain the placement and movement adequacy at the same time.

It was found that fit issues were identified by the fit models based on their own body specs and/or in comparison with previous samples they had tried on beforehand. Even though they were considered to have the most average body measurements, they possessed some specific body specifications that they found were off the average. Under code PERMANENT, answers from the interviews included "naturally one of my calf muscles is smaller" (Ava) or "my belly is a little fuller at the top" (Emma) to emphasize how the fit models made comments on top of their original physical features. Meanwhile, two of the female models from the interviews indicated the period as a temporary factor that affected body measurements with a comment such as, "as a woman, feeling a little full today" (Olivia). All the answers coded under *Body specs* showed how precisely the fit models understood their bodies and it has been their tacit knowledge. Oliver mentioned that he usually used his arms as a ruler and explained the following:

> *The arm length is a huge one. … And I know that 33 and a half is right there* (he was pointing at the part on this arm near his wrist). *And I know where all those sleeve lengths hit. And I know where the averages are. And you can be wherever you want in those averages.*

The other way the fit models identified fit issues was by comparing the new samples with the samples they tested before and recalling their experiences. For the same sample's initial and iterated prototypes, they compared the new sample over the initial one and described the difference. For example, they were asked to answer questions like "do you remember how the last one felt like" during the fit session. Moreover, the fit models were able to remember the tactile experience of the same garment made from different fabrics. Related to this, Ava mentioned that, "what the specs should be given a certain fabric type", was a comment she made in one of her past fit sessions.

Fit models' comfort comments and technical tacit knowledge

Through the first Descriptive Coding and the second cycle of Pattern Coding, comfort comments (Figure 19) that the fit models gave had a similar format. The codes that explained the fit models' comfort comments were 'discomfort area' and 'amount of ease'. Comfort comments were a combination of 'discomfort areas' they were experiencing with the 'amount of ease' they thought they needed to fix the discomfort, for example, "the front saddle of your arm of my armhole feels like it's diving into my arm, and I feel like I need about half an inch more front saddle" (Luna). It was found that how accurately the fit models sensed the garment and gave comments were related to their tacit knowledge skill levels. Ava shared her experience as being a very precise 'tool' of fit testing as the following:

> *I know this is kind of a bragging statement. But I remember working with one of my last clients and you know, tried the garment on and I said you know, I think this is like an eighth of an inch off. Because did you check the specs on it? And they look at the paper and they go 'oh my god'. So, I was really proud that I just had this very tactile ability.*

These comments on 'where' and 'how' to resolve the issues were appreciated within the fit session decision-making process. Emma explained how her comments were accepted during the fit sessions over her individual interview. The process was as the following:

> *I'm able to, "maybe a quarter", and that kind of gives them a ballpark. Then there's seam allowance and all these other things that come into play. So, me being able to say like,*

"maybe a quarter" helps them to be like, "okay, yes, but maybe three-sixteenth, because of seam allowance or whatever". Yeah, they use my thing. And then they add in their stuff to make an educated decision.

Suggesting pattern alterations such as making comments about the 'amount of ease' needed on garments were found to be the technical designer's tacit knowledge, but it was also found in fit models' comfort comments. It was more apparent in codes found in the Pattern codes, 'remote fitting setting', from Olivia, Oliver, and Luna's interview transcripts. Olivia, Oliver, and Luna were full-time fit models during the COVID-19 pandemic and were fitting an average of 25 brands simultaneously with over 14 years of experience as of 2022. They listed physical 'studio settings' they had for remote fittings such as "the correct color temperature of lights, it's 5600 overhead bar lights, I have front-facing LED light panels… I had a $7,000 camera, and my iPad as a mirror" (Oliver) and "we use Zoom, we used as I had, like two or three spotlights set up. And I had two different cameras, that you had a clip, I had a close-up camera that I could use to show detail. And then I had a camera that I would set for the entire landscape" (Luna). Besides the 'studio settings', they also had 'fitting room settings', which were full-length mirrors, clothing racks, steamed irons, scissors, pins, seam rippers, tape measures, and sewing machines right next to the fit models in the studio where they had remote fittings. Moreover, when they explained the fit session processes in remote conditions, the codes showed that they took over what technical designers and designers used to do in fit sessions. They found where 'discomfort area' was and demonstrated 'pattern alterations' based on their knowledge. Oliver described the process as the following:

I'm a half assistant tech designer at this point… I'll be like, you know, making adjustments and pulling things… And maybe not all fit models are capable of being like, *Oh, this is where you pin, you know, or I need to cut it. Like, I'll literally cut things and let them drop and do things like that. It's maybe a little bit less efficient, because most the time I'll take it off and put it back on to make sure I pin in a straight line.*

Luna also described the process as the following:

I took on a role of the tech designer, I basically became a technical designer while I was doing that. So you have to not only take the notes and communicate to your factories, or your pattern makers, but you also have to pin and mark on the garment so that they know exactly where you what part of the garment you're talking about. So it's about like creating that physical mark on the garment that you have to put on. In order to like, show exactly what sleeves you're talking about in the garment. So I was doing it. Yeah, it was like very much more technical design … I think I've been doing it long enough. I kind of did like three people's jobs in one and I was ready to take on the job.

Fit models' design comments and designers' tacit knowledge

Through the second cycle Pattern Coding, how the fit models performed their professions in fit sessions was identified in Figure 19. Although not all of the fit models gave 'design comments' as their profession and most of the fit models refused to give 'design comments', it was the opposite for Olivia, Ava, and Oliver, who had been in the industry for over 14 years as full-time fit models. Under the 'design comments' Pattern Code, 'customer's POV', 'length of garments', and 'how to wear' were identified as Descriptive Codes. Unlike designers or technical designers, who work in-house or work for only few brands at a time, fit models fit multiple brands at the same time being "the first customer of the garment" (Olivia). Given that the full-time fit models had clients of 25 apparel brands on average, they have been seeing and tried greater numbers of clothing than average customers, junior technical designers and/or designers. Oliver explained why fit session participants asked him for design comments as the following:

> *it's not my job to give design feedback … But inevitably, people start asking me, and designers start asking me for validation about their design ideas and things like that … one of the strange things about being a fit model is that, like, you got up every day, and went to the mall, and walk through every store in the mall and try it on everything in there. And you just did that every day all day. That's basically what I do. I fit for 30-40 brands. But every 30-40 brands they are bringing in 10-15 different reference styles. And so I literally see everything in market, plus see what everybody's planning to do a year or two from now. So, there is some design knowledge there, I would say, but you don't want to cross lines with intellectual property … But like, over time, I've come to realize how aware I am of design, even though it's not part of the job.*

Olivia's 'design comments' were to give feedback as a customer that some garments were not easy to wear as the following:

> *I am savvy because I've been in the business. But I also am like a regular customer that just goes in and like 'how does this work?' So if I'm back in the fitting room for 10 minutes, and like 'I don't know how to put this on!' Those swimsuits, Oh my gosh, there's so many straps. I don't know what goes where. And so that's important for me to come out and be like yes, if I can't figure this out and you guys are taking 10 minutes, then how is the regular person going to figure this out?*

The technical designer who was interviewed after the data analysis of the study mentioned that he only had one fit model with whom he worked over five years in his 40 years in fashion career. He also identified her as a professional fit model as he expected to share 'design comments' with her and respect her experience in the industry as a fashion expert.

So as a as a fit model, they had to give us a lot of feedback … they're not just fitting in the product, they're to treat themselves as the customer. If I want something like 'am I willing to buy this know', or they should have the idea to work with and they can give us some suggestion as well … Very important, besides telling us the fit, comfort, okay, now I can go on, then to let us know, maybe there's something to be better. You know, and it depends on the fabric and the trim, or depends on the design line depends on a lot of things, and we can discuss about it.

Fit models' tacit knowledge overlapped with technical designers' tacit knowledge and designers' tacit knowledge. When fit models make comments on how much the pattern should be adjusted, their tacit knowledge included what was considered technical designers' tacit knowledge. Moreover, when they discussed about the design, it came from their work experience of wearing numerous garments as professionals, and the tacit knowledge of aesthetics of garment designs overlaps with that of designers.

CHAPTER 5

DISCUSSION AND CONCLUSION

Fit assessments in apparel product development are repetitive decision-making processes among the experts as a group. Team members that participate in fit sessions run repetitive fit assessments over the new apparel product development until the fit issues are resolved. Resolving fit issues in apparel products is a very complex challenge. For example, when resolving fit issues on a jacket, the jacket shoulders are connected to the sleeves and the collar. Therefore, the fit issue on a particular part of the garment is interrelated to every other part it is connected to.

Fit sessions are typically the black box of apparel product development. Considering the immediate apparel product development environment changes due to COVID-19 and the constant pressure in the industry to digitize the processes, the present study focused on categorizing tacit knowledge in fit sessions and developing a framework to accumulate tacit knowledge for further use. Tacit knowledge and the decision-making process in fit sessions were investigated through fit session observations and individual interviews with technical design team members and fit models. Although the sample size was small, the study was novel in its approach and highlighted a potential for expansion. This study observed one apparel company's fit sessions to answer RQ1 and RQ2. Seven fit models were recruited to answer RQ2. The observation results were documented based on a framework proposed in the study and the individual interviews were coded and analyzed in figures. The observation results can be used as a baseline to elicit more tacit knowledge and to become a useful database.

For the first research question, RQ1, the power dynamics in fit sessions were examined. The power dynamics among the fit session participants changed in each fit session. It can be speculated that the determining factors for the decisions depended on the tacit knowledge of the participants, and their knowledge/information outside of the fit session, such as production viability. When the technical designer had the most knowledge regarding fit issues or solutions, the technical designer made the most effective comments and concluded the conversation. Some decisions were made by the designers because they had the most up-to-date information about the garment. It might seem like fit session participants with the most work experience had the strongest voice in the sessions because usually the quantity and quality of tacit knowledge correspond work experience. However, regardless of years of work experience that each participants had, they had their own professions and had the strongest voice when they were expertise of the topics.

Technical designer's tacit knowledge was found influential in persuading the other actors in pattern alteration solutions because appropriate pattern alteration suggestions enabled fewer rounds of fit sessions saving time and energy of all participants. The amount of the tacit knowledge that the technical designers had affected the team's performance of problem-solving. Therefore, the advanced level of the technical designer's comments was found to be essential when fit issues were complex. It was plausible that technical designers with advanced tacit knowledge performed better problem-finding (Shirley &Langan-Fox, 1996) and understood issues from a different angle (Leomard & Sensiper, 1998). When the pattern alterations from the observation were documented based on the improved team mental model, it was found that the technical designer was able to predict changes followed by the 'moving'. Schön and Wiggins (1992) stated that proficient designers with years of experience usually were able to predict expected and unexpected changes followed by 'movings'. Indeed, the proficient went through fewer rounds of 'moving' till they resolved every issue (Schön & Wiggins, 1992). Technical designers with advanced skill levels in pattern alteration were proved to go through fewer rounds of fit session and bring better solutions. Technical designers' comments were also valuable even when pattern alterations were merely aesthetic-related. During the observation of Garment 4, removing a seamline from the garment was confirmed by a technical designer. The technical designer confirmed that the seamline was a design line, and they did not need to add darts instead. Even though the pattern alteration in fit sessions was design manipulations, technical designers' knowledge of garment construction was essential. Therefore, pattern alterations in fit sessions were a team decision-making process that incorporated layers of technical designers' tacit knowledge.

Referring to the observation result of Garment 3, the misfit of the garment was identified by the fit model. Even the visual clues from the garment were pleasing to technical design team members except for the fit model and they were happy with the silhouette of the sleeves when investigated in a standing pose with arms down. The pattern alteration was followed after the fit model commented on her tactile and comfort experiences, which were captured during her movements. Some areas were difficult to get visual clues such as armholes or crotch areas. Moreover, these areas were where people made large movements that could lead the garment to twist and turn. In this manner, fit models' verbal comments were essential. They not only confirmed the fit issues detected from visual clues but also brought up new fit issues that only could be detected by wearers. Proficient fit models, who were used to technical jargon used in the fashion industry, were able to give tactile feedback referring to each very small part of their bodies separate and were familiar with fractions and numbers. The verbal feedback of fit models with accurate solutions was valued within the technical team and selected as final decisions. Designer's decisions were weighted when they had specific design intentions to meet, and technical designers could bring multiple fit correction suggestions. Referring to the Garment 4 observation, the designers explained their intentions and the technical designer suggested corresponding pattern alteration to proceed. It worked the other way for Garment 3 that the technical designer suggested pattern alteration and the designers limited the options according to their design intentions. In both of cases, designers' comments weighed the most in making final decisions. Although technical designers and designers work as a team, designers affected the final decisions the most when the design missions of garments got priorities.

For the second research question, RQ2, based on the fit session observation results, the technical designer was found to collect visual clues of fit/misfit and verbal clues from fit models. When she found visual clues, she asked related questions to fit models to make sure whether they were misfits caused by garment constructions. These two clues established the baseline to start searching for pattern alteration options. They collaborated in finding fit issues by combining their visually-observed (observed fit) and sensory-observed (experienced fit) information. Although technical designers seemed to jump into fit solutions in a second during fit sessions, they followed if-then decision trees to extract the most suitable fit solutions. The tacit knowledge was composed of successive causal relationships which could be explained in common words if a significant amount of time to follow each element was given. The skill level of pattern alteration determined how the technical designer solved fit issues. The study was conducted as a case study so it could not include many technical designers from different skill levels of pattern alteration.

Throughout the study, although some tacit knowledge of technical designers was elicited, some of the tacit knowledge of the fit models could not be elicited. To be specific, the tacit knowledge of the fit models was closely related to how one subjectively senses their body. Every person sensed their body differently and every body part sent different sensing results to their brains. This could be considered personal recordings but could not be explicit knowledge as the content could not be shared, taught, or accumulated without the context in the first place. It also could be the reason why new technologies were not able to help the apparel product development process enough, especially during the fit session stage. For example, tension maps in virtual fitting software do not incorporate what fit comments from fit models were like. Tension map studies that aim to understand the garment fit cannot explain the difference between "snug" and "digging into" or determine how much tension brings an 'aesthetically pleasing" look on human bodies. In a sense, what fit models are doing cannot be 100% substituted by technologies that we have at the moment. Yet, fit models' tacit knowledge which was customized to each of them had been accumulated over the years from countless clothes trying-on. Their tacit knowledge included ways to identify fit issues, suggest the following solutions, and a massive database of apparel styles from various labels. How they identified and verbalized the fit issue was considered objective and applicable which enabled fit models' tacit knowledge to be utilized in the decision-making process.

Besides answering the research questions, it was found that documenting fit sessions itself would be very beneficial to systematize fit session discussions. As the discussion include wide variety of topics such as design aesthetics, fabric properties, fit issues, functional aspects of garments, and production lead time, it would be helpful if a table of elements that need to be incorporated in making decisions is identified. One of the elements that were identified in Garment 4 was fabric spec. If the fabric spec was not mentioned in the discussion, the pattern alteration confirmed in the fit session could have been dismissed on the manufacturing stage and come back to another round of fit session.

The present study had some limitations in the number of cases and interview participants. More than 20 companies were contacted to observe their fit sessions but getting consent from the legal teams of the companies was very difficult. Collecting artifacts, or taking pictures were not allowed. In previous attempts, companies did not want the data to be a part of publications, etc. therefore the present study progressed very slowly. Many of the previous studies might have encountered similar situations if they wanted to observe fit processes as what was happening in fit sessions has been company secrets and professional tacit knowledge, as described by Tellis (1997). During the case study, pattern alterations marked on actual 2D pattern blocks were not collected for data because the company was outsourcing the patternmaking from its manufacturers. In addition, the technical designer in the case study was not interviewed in detail because she was a freelance patternmaker and there were concerns about data infringement. Recruiting professional fit models for individual interviews also proved to be a challenge as they also were under NDAs with some apparel companies. Another limitation was the fact that the observed fit session was scheduled for the second sample of the collection. Therefore, the identified fit issues were rather minor as initial fit issues were already solved from the previous round of fit sessions from the first sample. Although the case study of the study had some limitations, a few major companies were secured for future interviews and observations as of November 2022 for the continuation of the study.

Another limitation was the fact that not all of the actors were included in the study (such as merchandisers and manufacturers). As the fit session participants bring their expertise to the discussion and take part in the decision-making with their knowledge, the fit session might have had more information if there were other participants with more diverse occupations such as merchandizers or manufacturers. If a merchandiser had been in fit sessions, it might have included the sales information or whether the certain design of garments was top-rated. Future studies in different apparel companies with some additional fit session participants would enrich the study.

As the case study was limited to one apparel company, it was challenging to observe every different relationship among fit session participants. There has been a gap between how fit models described how they perform their professions and fit session observation results from the case study. Most fit models from individual interviews were full-time fit models with over 14 years of experience who had clients from over 20 brands every year. They would have gained much tacit knowledge in the fashion industry. And some apparel brands have been their clients for more than five years. The years of revisiting the same companies and getting used to their styles and relationship with other fit session participants may help them give various comments including fit comments and design comments. On the other hand, two fit models who participated in fit session observations had been with the company for about two years and relatively have short work experience as fit models. And both of them were not full-time fit models. It might have affected the comments they were making in fit sessions. How fit models with much experience comment was described by an additional interview with a technical designer. It could also be supported by future studies observing more fit session settings.

Some suggestions for future studies and technology development were developed from the study. Current virtual fitting software companies are paying tremendous attention to measuring fabric's mechanical properties correctly to improve the simulation of virtual garments. In addition to the plain fabric matrix, the physics of fabrics with fusible interfacing should be tested and included in virtual fitting technologies. Referring to the observation of Garment 2, the shirt was a revised version of the original shirt that already met the fit standards and was on sale in the market. The only revised element was the fabric, seersucker. However, the interfacing which had been used for the original shirt was way too thick for sheer seersucker fabric. Moreover, the pattern piece of the collar shrank when interfacing was applied and made the piece even stiffer. Fabric properties and their correlation with interfacing could have been investigated before the new sample had been tested before it was made to preempt fit issues. Once the apparel company chooses to try new fabric, fabric properties, finishings, and their correlation with interfacings could be investigated and tested on swatches beforehand to minimize the fit session iterations. When an apparel brand decides to change only the fabric from the original design, proper virtual technology with physics data of both fabric and interfacing can support the process.

During the observation of the fit session, one of the designers was holding garment spec charts. Each chart showed measurements for a garment that was measured from more than ten points of a garment piece. And it contained the measurements of all different sizes of the same design garment. They tried their best to maintain a consistent look on different sizes. Virtual fitting technologies with diverse-size avatars could support the grading part of apparel development. Even though they may not be suitable for detailed fit sessions but would be enough to confirm the consistent silhouette of the garment in various sizes. Derived from the results of the study, future studies should examine how technical designers should perform the grading of mass-produced garments. Grading is aimed at producing the same look between different sizes. The process might involve various sizes of fit models and investigating how garments interact with bodies. Future studies on grading would enrich our understanding of garments in multi-faucets.

In summary, the present study identified how each technical team member contributed to the group decision-making process in fit sessions. Moreover, it suggested a combined model, i.e., the improved team mental model, which was found to be effective in recording the fit session conversations. Although the sets of seeing-moving-seeing documentation from the study were a part of the fit alterations, they would be a history of fit adjustments of each garment once documented from the proto-sample stage to the production sample stage. The improved team mental model has room to be enhanced further and could be applied to future data collections. The data sets recorded in the study based on the theoretical framework included levels of visual clues, additional information that impacted pattern alteration decisions, and which comment affected the final decision the most. The distinguishing feature of data sets is their viability in translating them into quantitative data. For instance, the levels of visual clues identified from the study indicate that certain visual misfit clues need urgent alterations. The numbers of arrows that indicate causal relations between the elements stress the determining factors in the decision-making process. Once future studies add sufficient visual clues from different types of garments, the data set could benefit following fit sessions by specifying which visual misfits to concentrate on to resolve multiple related misfits.

The improved team mental model could also be updated with multiple colors to label each fit session participant and additional information. Who made the comments was not important in the original team mental model because it was meant to collect comments not identify the power dynamics. However, by following the speaker of the comments, the theoretical framework could also be used as a tool to understand power dynamics among fit session participants. Moreover, the manufacturing viability, which was additional information, was found to be one of the deciding factors of pattern alterations although it was not related to garment construction details. Accordingly, additional information such as the physics of new fabrics served as essential information which impacted both the design and fit of the garment. These significant but not construction-related information could be highlighted in color themed theoretical framework and form a list to support the fit session decision-making process. The list would contribute to itemizing diverse sorts of information from design elements to manufacturing limitations to reduce trials and errors.

The findings of the study indicated that there are useful ways to elicit tacit knowledge in fit sessions. Tacit knowledge collected, stored, and shared would be essential for further uses such as digitizing decision-making or developing a new technology to support the apparel product development process. An in-depth understanding of fit models' tacit knowledge would start a new conversation on how to define the concept 'fit' and fitting on human bodies. Discussion topics identified in the observation could be extended to manuals to check if every condition was considered when making decisions during fit sessions.

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APPENDIX I: IRB APPROVAL

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Institutional Review Board for Human Participants

Notice of Exemption

To:	Yoon Yang
From:	Andrew Willford, IRB Chairperson
Protocol ID#:	2108010491
Protocol Title:	Decoding tacit knowledge in apparel product development
Approval Date:	September 10, 2021
Expiration Date:	None

Your protocol has been granted exemption from IRB review according to Cornell IRB policy and under paragraph(s) 2 of the Department of Health and Human Services Code of Federal Regulations 45CFR 46.104(d).

• Paragraph 2 allows to be exempted from IRB review research activities in which the only involvement of human subjects will be in the following category: Surveys/Interviews/Standardized Educational Tests/Observation of Public Behavior – Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior if: i) information obtained is recorded in such a manner that human subjects cannot be identified, directly or through identifiers linked to the subjects; or ii) any disclosure of the human subjects' responses outside the research would not reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability or reputation.

Please note the following:

- Investigators are responsible for ensuring that the welfare of research subjects is protected and that methods used and information provided to gain participant consent are appropriate to the activity. Please familiarize yourself with and conduct the research in accordance with the ethical standards of the Belmont Report (https://www.hhs.gov/ohrp/regulations-and-policy/belmont-report/index.html).
- Investigators are responsible for notifying the IRB office of change or amendments to the protocol and acquiring approval or concurrence **BEFORE** their implementation.
- Progress reports, requests for personnel or other administrative changes, or requests for continuation of approval are not required for the study. However, upon conclusion of the study, please submit a Project Closure form: http://www.irb.cornell.edu/forms.

For questions related to this application or for IRB review procedures, please contact the IRB office at irbhp@cornell.edu or 607-254-5162. Visit the IRB website at www.irb.cornell.edu for policies, procedures, FAQs, forms, and other helpful information about Cornell's Human Participant Research Program. Please download the latest forms from the IRB website www.irb.cornell.edu/forms/ for each submission.

Cc: Fatma Baytar

APPENDIX II: Fit Model Interview Questions

[Overview]

1- What is your occupation?

2- How long have you been working as a fit model?

3- Which companies have you worked with? (to understand the products categories)

4- What kinds of garments have you usually fit tested?

5- How do companies make sure that you are the right fit model for them?

[Fit session settings]

1. At the fit sessions, are you allowed to look at yourself in the mirror? If so, do you usually have full length mirror in the fit sessions?
2. Do you stand still or move/walk when you are fitting garments? If depends on the type of garments, please elaborate. How long? How often/ repetitive?
3. Have you tried the same garment twice before and after the fit correction? If so, how did your comments affect the design/fit/fabric/detail of the garment?
4. Have you ever had a disagreement with designers in fit sessions referring to the fit of garments? How did the conversation go?

[Fit models' comfort feedback/ tacit knowledge]

1. When you fit test different type of garments, do you have specific parts in particular that you focus on according to the types of garments? (e.g., "I double check the waist level in wrap dresses in particular).
2. Do you get information about the target customers during the fit sessions? How do you modify your comments if you consider the target customers? Please elaborate.

3. If you find the garments uncomfortable/tight in some areas, how do you determine whether it is the design that caused the issue, or the overall sample size is off? Or do you leave it to designers and give simple comments that the part is uncomfortable?
4. Some garments are tight for aesthetic reason (e.g., jeans). What is your own definition of fit/your own criterion, distinguishing tightness for aesthetic and unfit? (Based on different garment types)
5. How do you make comments when you as an individual have certain preference in design or in tightness of garments?
6. What kind of comments do you make besides the tactile experiences (fabric or seam finishes on the skin)? Do you take suggestions on pattern modifications?
7. How soon do you test the next garment? Does the technical team give you some time to forget the comfort feeling from the first garment that you tried on?

APPENDIX III: In-person Fit session Observation Protocols

1. Researcher meets with the technical designer (TD), debriefs them about the study, and collects their consent. The researcher will prepare two copies (one for the participants and one for the researcher's records)
2. Upon receiving approval from the company, the researcher will audio-record the conversations for transcription and be ready to take pictures from the process. For audio-recording and taking pictures, the researcher will use a smartphone. The recording will begin when the fit session discussions begin. The most important pictures to take would be the ones that visually show problematic areas and suggested solutions:
    a. Markings on the garments
    b. Markings on the patterns
    c. Team's alterations on the garments (holding, marking, pinching, pinning, when they point at something on the garment)
3. Researcher will ask for permission from the company if she can collect fit notes taken during the fit session
4. Researcher will ask for permission from the company to have access to the original and iterated patterns of the garment for before-after comparisons (to have an example to see how team meetings and discussions contributed to pattern improvement)
5. Immediately after the fit session, the researcher will have a journal entry to reflect on the process and add "thick descriptions". The format of the journal entry is as follows:

Descriptive Notes (Measurable data. No assumptions are made)	**Reflective notes** (researcher's thoughts w/ some interpretations that may not be correct. These notes will be shared with TDs for member checking)

6. On the day of the fit session the researcher will transcribe the session immediately before she forgets the details

7. Once the data analysis is completed, findings, quotes, and descriptions will be shared with the participants/ with the company for member-checking (validity)