

Comparative Study of Paper Materials for Tactile Pop-Up Books for Visually Impaired Children in Cultural Heritage Communication

Zixiang Lin^{1*}, Keer Tang¹

¹School of Design, Dalian Minzu University, Dalian, 116600, China.

*Corresponding author. E-mail: 514732009@qq.com;
Contributing author: 2156387282@qq.com;

Abstract

In the context of cultural heritage dissemination, visually impaired children face difficulties in accessing information through visual media. Using tactile pop-up books as a medium, the impact of paper materials on tactile reading experience is examined. By constructing substitute geometric models, four types of paper—high-white cardstock, standard cardstock, model cardstock, and cotton paper—are compared in terms of formability, durability, safety, and tactile quality. The results indicate a trade-off between structural performance and tactile experience: high-white cardstock shows the best overall performance; standard and model cardstock provide stable structures but limited tactile comfort; cotton paper offers better tactile comfort and safety but weaker formability. It is suggested that material selection or combination should be based on functional requirements to achieve a balance between structural integrity and tactile experience, providing references for accessible cultural heritage dissemination.

Keywords: Tactile Pop-up Books, Visually Impaired Children, Paper Materials, Cultural Heritage Dissemination

1 Introduction

In the contemporary context of cultural communication, the presentation and dissemination of cultural heritage largely rely on visual media, such as images, exhibitions, and printed publications. By the end of 2024, the total number of registered museums nationwide had reached 7,046, an increase of 213 compared to 2023, receiving approximately 1.49 billion visits [1]. While this visually dominant mode of information delivery enhances public cultural awareness, it also, to some extent, overlooks the perceptual needs of visually impaired groups—particularly the issues of participation and accessibility for visually impaired children in acquiring cultural knowledge. Therefore, how to achieve accessible dissemination of cultural heritage information through design has become an important issue in visual communication design and the development of social inclusivity.

On September 1, 2023, the Barrier-Free Environment Construction Law of the People's Republic of China was officially implemented, clearly defining the responsibilities and directions for providing accessible services to people with disabilities and the elderly from a legal perspective [2]. In this context, cultural heritage, as an important carrier of Chinese civilization, holds both practical necessity and equity significance in its dissemination to visually impaired children. Previous international studies have shown that incorporating detailed explanations and tactile guidance into museum exhibitions and educational activities can effectively enhance visually impaired individuals' understanding and engagement with cultural artifacts [3]. However, since a large proportion of cultural heritage objects and architectural forms rely heavily on visual representation, traditional modes of dissemination remain difficult for visually impaired children to perceive, making it necessary to move beyond visually dominant forms of expression. Tactile pop-up books, by integrating tactile graphics with three-dimensional structures, transform visual information into perceivable spatial forms, thereby supporting the development of mental imagery and enhancing comprehension through multisensory interaction.

Taking cultural heritage dissemination as the application context, this study focuses on the reading needs of visually impaired children by selecting multiple paper materials to construct tactile pop-up book prototypes with a unified structure. These materials are comparatively analyzed in terms of formability, durability, safety, and tactile quality, aiming to reveal the mechanisms by which materials influence tactile reading experiences and to provide references for accessible design practice.

2 Research on Tactile Reading and Tactile Pop-up Book Design

A. Tactile Reading and Tactile Graphics

Reading methods for visually impaired individuals can generally be categorized into tactile reading, visual reading (for those with residual vision), and auditory reading [4]. Among these, tactile reading is one of the primary means of accessing information, relying on the sense of touch to perceive and interpret form, texture, and spatial relationships. Existing tactile reading systems typically construct clear hierarchical structures using basic elements such as points, lines, and surfaces, thereby enhancing recognition efficiency and

the accuracy of information transmission [5]. At the same time, tactile cognition is characterized by sequential and path-dependent processes, in which readers gradually acquire information through finger movement. Therefore, tactile graphic design must take into account the continuity and logical organization of touch paths.

In the context of children's education, tactile graphics not only serve as a medium for information transmission but also play an important role in cognitive development. Studies focusing on visually impaired children emphasize that factors such as recognizability, size control, and spacing between elements directly affect tactile comprehension. Consequently, simplifying graphic forms while maintaining informational integrity has become a key direction in tactile design research.

B. Conventional Pop-up Books and Tactile Pop-up Book Design

Conventional pop-up books are primarily designed for children with normal visual abilities, with visual experience as the core focus. Through the unfolding and transformation of three-dimensional structures, they enhance spatial layering and reading engagement [6]. In such books, structural design serves image and narrative expression, emphasizing color and form for visual presentation, while touch functions mainly as a supplementary interaction. Some intricate structures are not suitable for frequent handling in order to avoid damage. From a material perspective, conventional pop-up books typically prioritize print quality and visual appearance, often using smooth-surfaced paper. However, under repeated handling, these materials are prone to fold fatigue and structural damage, resulting in limited durability and adaptability for tactile use (Fig.1).



Fig. 1 Conventional pop-up books

In contrast, tactile pop-up books are designed for visually impaired children who rely primarily on touch for perception. Their design focus shifts from “viewing” to “tactile reading,” where touch becomes the primary means of information acquisition. This shift requires three-dimensional structures to maintain stability under repeated handling, while enhancing tactile recognizability through simplified forms and emphasized contrasts. In this context, materials not only serve as structural support but also directly affect tactile clarity, durability, and reading safety. Therefore, compared with

conventional pop-up books, tactile pop-up books impose higher comprehensive requirements on paper materials, making it necessary to systematically compare and analyze their performance in tactile reading contexts.

C. Paper Materials and Tactile Reading Experience

In publications designed for visually impaired individuals, the selection of paper serves as a fundamental basis for ensuring effective transmission of tactile information. According to the national standard GB/T 22826-2008 [7], such materials typically use paper with a grammage of approximately 125 g/m², featuring good smoothness, abrasion resistance, and tensile strength to meet the basic requirements of planar tactile reading. However, when tactile reading extends to pop-up books with three-dimensional structures, material requirements become more complex: paper thickness and stiffness affect structural stability; surface texture influences the clarity of tactile recognition; durability and flexibility determine service life; and edge treatment and material strength are directly related to user safety. Relevant studies have shown that introducing materials such as suede-like fabrics instead of conventional cardstock in tactile picture books for visually impaired children can significantly improve the accuracy of tactile recognition [8], demonstrating the important role of material differentiation in enhancing tactile experience.

Existing research, however, has largely focused on single material properties or planar contexts, and lacks systematic comparison of the comprehensive performance of different paper materials in tactile pop-up books. Particularly in the context of cultural heritage dissemination, materials must simultaneously meet multiple requirements, including structural stability, tactile clarity, and safety. Therefore, it is necessary to conduct a systematic evaluation of different paper materials from the perspective of overall tactile experience, in order to provide a scientific basis for material selection in the design of tactile pop-up books for visually impaired children.

3 Research Methods

A. Research Approach and Framework

This study focuses on the impact of paper materials on tactile reading experience in tactile pop-up books, adopting a combination of design experimentation and user experience evaluation to comparatively analyze the performance of different paper materials in tactile reading contexts. An evaluation framework oriented toward material properties is established, assessing paper materials across four dimensions: formability, durability, safety, and tactile quality. By controlling the consistency of three-dimensional structures and graphic content, paper material is treated as the primary variable. The study is carried out through three stages—prototype construction, experimental testing, and result analysis—in order to systematically examine differences in material application and to reveal the intrinsic relationship between material properties and tactile reading experience.

B. Experimental Prototypes and Substitute Geometric Design

To ensure comparability and clarity in structural expression, this study introduces a “substitute geometry” approach, using basic geometric forms as the construction units for tactile pop-up book prototypes. Ten typical geometric forms are selected, including cube, cuboid, cylinder, cone, sphere, triangular prism, triangular pyramid, quadrangular prism, frustum, and truncated cone, and corresponding three-dimensional samples are produced. These forms feature clear structures and distinct tactile characteristics, enabling effective comparison of different paper materials in terms of three-dimensional formation and tactile recognition under controlled variables. At the same time, these basic forms correspond closely to common artifacts and architectural structures in cultural heritage, serving as abstract representations of more complex forms. Thus, the experimental results not only support material comparison but also provide methodological references for the tactile translation of cultural heritage forms.

C. Experimental Materials and Evaluation

In the production of tactile pop-up books, material selection is a key factor in balancing tactile clarity, structural stability, and user safety. Compared with conventional books, tactile pop-up books must account for the tactile characteristics and reading behaviors of visually impaired children. For example, during tactile interaction, fingers may sweat due to physiological or environmental factors; therefore, paper materials should provide appropriate tactile qualities and a certain level of moisture absorption to ensure stable tactile feedback. In addition, under conditions of repeated touching and folding, materials must exhibit sufficient fatigue resistance and structural support to prevent discomfort or deformation caused by excessive hardness or softness, which could affect both reading experience and safety.

Based on these considerations, multiple paper materials with varying thicknesses and grammages are selected for comparative testing, including standard cardstock (approximately 0.5 mm, 400 g/m²), cotton paper (0.6 mm, 350 g/m²), model cardstock (0.5 mm, 400 g/m²), and high-white cardstock (0.4 mm, 400 g/m²). These materials differ in thickness, stiffness, and surface properties, providing a basis for analyzing their performance in tactile three-dimensional structures (Fig.2). During evaluation, the four established criteria—formability, durability, safety, and tactile quality—are applied to conduct a comprehensive analysis of each material’s suitability for tactile pop-up book design.

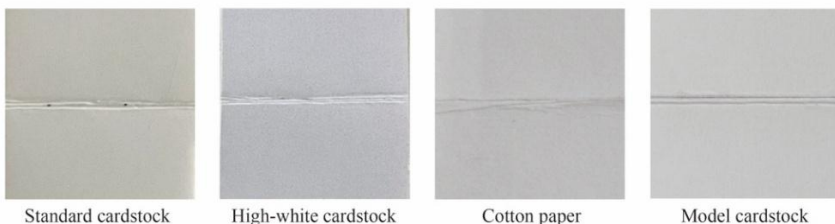


Fig. 2 Comparative Testing of Paper Materials

D. Participants and Data Collection Methods

Eight visually impaired children are recruited as the primary participants, with additional observational support provided by teachers or relevant professionals. The experiment is conducted in a quiet, distraction-free environment to ensure participants' focus on tactile reading tasks.

Data collection adopts a multi-method approach, including four components: (1) tactile recognition tests, recording participants' identification of different geometric forms; (2) rating scales, using a five-point scale to evaluate tactile clarity, structural stability, and reading comfort; (3) behavioral observation, documenting touch paths, dwell time, and page-turning actions; and (4) brief interviews, gathering participants' perceptions and preferences regarding different materials. The integration of these methods enhances both the reliability and interpretive completeness of the results.

E. Evaluation Indicators and Analysis Methods

Based on the design requirements of tactile pop-up books, this study establishes four evaluation indicators to analyze paper materials:

(1) **Formability**: refers to the forming effect and structural stability of paper in three-dimensional structures, including folding clarity and structural retention.

(2) **Durability**: refers to the material's resistance to wear and damage during repeated touching and page-turning.

(3) **Safety**: refers to edge characteristics and the risk of damage during use.

(4) **Tactile Experience**: refers to the influence of surface properties on tactile recognition and comfort during touch.

To ensure the reliability and interpretability of the data, all evaluations were independently conducted by eight participants. A five-point scale was adopted for scoring, and mean values were used for statistical analysis. The final scores of each material under different indicators were calculated as the average of the raw data. Non-integer results reflect individual differences among participants and variations in subjective perception.

4 Research Methods

A. Comparison of Formability

Under consistent three-dimensional structural conditions, different paper materials exhibit significant differences in geometric form construction Fig.1. The experimental results show that high-white cardstock performs best in terms of folding clarity and structural retention, producing stable three-dimensional forms with clear edges. Standard cardstock and model cardstock perform well during the initial formation stage; however, repeated folding leads to fiber shedding, resulting in reduced fold-line clarity and consequently affecting structural stability. In contrast, cotton paper, due to its relatively soft material properties, provides insufficient structural support, causing some forms to lack rigidity after unfolding and demonstrating weaker formability. In addition, model cardstock, which combines a coated surface with a matte side, experiences uneven stress during folding, further intensifying edge wear. Overall, the stiffness and surface treatment of materials play a crucial role in

the formation of stable three-dimensional structures.

Table 1. Comparison of Formability Performance of Different Paper

Material	Folding Clarity	Structural Stability	Average
High-white cardstock	5	5	5.0
Model cardstock	5	4	4.5
Standard cardstock	4	4	4.0
Cotton paper	3	4	3.5

B. Comparison of Durability

Under conditions of repeated folding and tactile interaction, significant differences in durability are observed among the paper materials Fig.2. The results indicate that high-white cardstock maintains good structural integrity after multiple folds, with no evident deformation or collapse, demonstrating high durability. Standard cardstock and model cardstock show similar performance; due to their relatively high stiffness, they retain structural form well during repeated use, although fold lines gradually deepen and localized material fatigue appears. In contrast, cotton paper, being relatively soft, is more prone to deformation under external force, with some structures collapsing after repeated use, indicating weaker durability. Additionally, the difference between the coated and matte surfaces of model cardstock may lead to uneven stress distribution, further affecting its stability. Overall, material stiffness and structural support capacity play a crucial role in durability, and papers with moderate hardness are more suitable for long-term use.

Table 2. Durability Evaluation of Different Paper Materials

Material	Material Crease Degradation	Structural Deformation	Structural Retention	Average
High-white cardstock	5	4	5	4.7
Standard cardstock	4	4	5	4.3
Model cardstock	4	4	5	4.3
Cotton paper	3	3	3	3.0

C. Comparison of Safety

In tactile pop-up books, material safety is mainly reflected in edge tactility, structural stability, and the risk of damage Fig.3. The results show notable differences among materials. Cotton paper, due to its softness, has relatively smooth edges that are less likely to produce sharp sensations; even after repeated use, it rarely develops cracks or hard edges, resulting in higher overall safety. High-white cardstock, while structurally stable, may produce relatively hard edges at fold lines due to its stiffness, making it slightly less safe than cotton paper.

In contrast, standard cardstock and model cardstock tend to have sharper edges after cutting and folding, which may cause discomfort during touch. With repeated use, edge wear or small cracks may develop, increasing potential risks. Furthermore, the coated structure of model cardstock may lead to

irregular edges under uneven stress, further affecting safety. Overall, material flexibility and edge characteristics are key factors influencing the safety of tactile pop-up books.

Table 3. Safety Evaluation of Different Paper Materials

Material	Edge Tactility	Damage Risk	Average
Cotton paper	5	4	4.5
High-white cardstock	4	4	4.3
Standard cardstock	3	4	3.7
Model cardstock	3	4	3.7

D. Comparison of Tactile Quality

Tactile quality is a critical factor influencing the reading experience of tactile pop-up books, mainly reflected in friction characteristics, surface comfort, and adaptability to hand moisture. The results show significant differences among materials. High-white cardstock performs best, featuring a clean surface and good moisture absorption, which helps absorb sweat and maintain dryness during touch; its moderate stiffness also ensures a smooth and comfortable tactile experience. Cotton paper, with its fibrous structure, can absorb some moisture and provides moderate friction, resulting in relatively high comfort, though it is slightly less effective in fine detail recognition.

In contrast, standard cardstock tends to produce increased friction when fingers are moist, leading to a “sticky” sensation that disrupts the continuity of touch. Model cardstock, due to the difference between its coated and matte surfaces, presents uneven tactile feedback and increased resistance, resulting in a less favorable tactile experience. These findings indicate that moisture absorption and surface friction properties significantly influence tactile reading experience.

Table 4. Tactile Experience Evaluation of Different Paper Materials

Material	Friction Appropriateness	Moisture Absorption	Comfort	Average
High-white cardstock	5	5	5	5.0
Cotton paper	4	4	5	4.3
Standard cardstock	4	3	5	4.0
Model cardstock	3	2	4	3.0

E. Comprehensive Comparative Analysis

Based on the four evaluation criteria—formability, durability, safety, and tactile quality—clear differences and trade-offs can be observed among the materials. Overall, high-white cardstock demonstrates the most balanced performance, excelling in formability, durability, and tactile quality, and offering both structural stability and a comfortable tactile experience. Standard cardstock and model cardstock perform well in formability and durability, making them suitable for structures requiring higher rigidity; however, they show limitations in safety and tactile comfort, particularly under conditions of finger moisture. In contrast, cotton paper performs well in tactile comfort and safety but lacks sufficient stiffness, leading to deformation in more complex

structures and limiting its applicability.

Further analysis reveals a clear trade-off between “structural performance” and “tactile experience”: materials with higher stiffness tend to enhance structural stability but may reduce tactile comfort, while softer materials improve tactile experience but provide weaker structural support. Therefore, in tactile pop-up book design, material selection or composite application should be adapted to specific functional requirements in order to achieve a balance between structural integrity and tactile experience.

Table 5. Comprehensive Performance Comparison of Different Paper Materials

Material	Formability	Durability	Safety	Tactile Experience	Overall Performance
High-white cardstock	5.0	4.7	4.3	5.0	Excellent
Standard cardstock	4.0	4.3	3.7	4.0	Good
Model cardstock	4.5	4.3	3.7	3.0	Fair
Cotton paper	3.5	3.0	4.5	4.3	Good

5 Conclusion

In the context of cultural heritage dissemination, visually impaired children represent an important audience whose modes of information acquisition and cognitive pathways differ significantly. Addressing the limitations of visually dominant information that is difficult for them to perceive, this study employs tactile pop-up books as a medium and examines the role of paper materials in shaping tactile reading experiences. By constructing an experimental model based on substitute geometric forms and comparing different materials across four dimensions—formability, durability, safety, and tactile quality—the results reveal clear differences and trade-offs between structural performance and tactile experience. Among the materials tested, high-white cardstock demonstrates the most balanced overall performance; standard cardstock and model cardstock show good structural stability but relatively limited tactile comfort; while cotton paper performs well in tactile quality and safety but has weaker formability.

The findings indicate that material selection in tactile pop-up book design should be tailored to specific functional requirements or combined strategically to achieve a balance between structural performance and tactile experience. From the perspective of cultural heritage dissemination, transforming complex forms into perceivable geometric structures and expressing them through appropriate materials can enhance visually impaired children’s understanding and engagement. The substitute geometry method proposed in this study provides a feasible approach for the tactile translation of cultural heritage forms and offers practical guidance for material selection in accessible design. At the policy level, the Barrier-Free Environment Construction Law and the 14th Five-Year Plan for the Protection and Development of Persons with Disabilities provide clear direction for accessible dissemination. Future research may further integrate multi-material combinations, multisensory design strategies, and digital technologies to expand applications in cultural heritage communication and promote equitable access to cultural resources.

References

- [1] Zheng, J.: Construction of cultural heritage exhibition systems from the perspective of cultural communication—A case study of the “Cultural Heritage” series at the Yangzhou China Grand Canal Museum. *Southeast Culture* (05), 128–135 (2025)
- [2] The State Council of the People’s Republic of China: Barrier-Free Environment Construction Law of the People’s Republic of China. Available at: https://www.gov.cn/yaowen/liebiao/202306/content_6888910.htm(2023)
- [3] Vaz, R.D., Freitas, D., Coelho, A.: Blind and visually impaired visitors’ experiences in museums: Increasing accessibility through assistive technologies. *The International Journal of the Inclusive Museum* 13(2), 57–80 (2020)
- [4] Lin, Y.: An empirical study on the social support system for accessible reading among the visually impaired—Based on a survey of 112 respondents. *Library and Information Service* 57(24), 84–89 (2013)
- [5] Xu, J., Lin, Z., Gao, H., et al.: Research on tactile-visual integrated cognitive graphic design for visually impaired children. *Packaging Engineering* 44(04), 255–261 (2023).
- [6] Tang, L.: Current status and innovation directions of children’s pop-up book publishing in China. *Publishing Wide Angle* (11), 64–67 (2022).
- [7] Standardization Administration of China: GB/T 22826-2008 Braille printing paper (2008)
- [8] Zhang, Y.: Research on tactile preferences and design applications in picture book reading for visually impaired children. *Packaging Engineering* 45(24), 254–260 (2024).