APPLICATION OF ANAMORPHISM IN PRODUCT DESIGN

Kettley, Calum;
Wodehouse, Andrew

University of Strathclyde

ABSTRACT

This research aims to investigate the incorporation of anamorphism into product design and has resulted in the creation of a series of handheld objects with embedded anamorphic information. Anamorphism is a phenomenon typically applied to images, where it appears distorted from all but one angle. Often associated with optical illusions, its history and viability for application to product design are reviewed. This includes an assessment of different designs' impact on the overall recognition of hidden anamorphic objects, focusing on their design attributes to determine the best at concealment. With the creation of 3D anamorphic objects, experiments were conducted to allow correlations between object visibility and design features to be identified. Analysis of the results showed that objects with vertically stretched text and wider cuts within the characters were hardest to recognise and therefore more secure. Objects with the least material made it more difficult to interpret the hidden information from positions that were not the "privileged viewing zone". The creation of these anamorphic objects highlighted that this function of anamorphism is possible and could be incorporated within products in future.

Keywords: Anamorphism, Conceptual design, Creativity, Industrial design

Contact:
Wodehouse, Andrew James
University of Strathclyde
United Kingdom
andrew.wodehouse@strath.ac.uk

Cite this article: Kettley, C., Wodehouse, A. (2023) 'Application of Anamorphism in Product Design', in *Proceedings of the International Conference on Engineering Design (ICED23),* Bordeaux, France, 24-28 July 2023. DOI:10.1017/pds.2023.60

1 INTRODUCTION

When considering "design in a complex world", there is reassurance and simplicity to be found in objects where only one viewpoint can be correct. Anamorphism is a concept that takes advantage of visual perspective, where the undeformed anamorphic image is only visible from a single or a select few viewpoints. From all the other angles the image appears distorted to the observer and often unrecognisable. Anamorphosis is often associated with optical illusions due to depth misperception experienced by observers. In many cases, observers believe they are viewing a three-dimensional object, however upon moving from the viewpoint they realise it is a flat image that comes to life from the correct perspective. This paper seeks to explore how the phenomenon can be usefully applied in product design contexts.

The word anamorphosis originates from the combination of two Greek words, ‘ana’ meaning again/ back and ‘morphoun’ meaning to shape (Ravnik et al., 2014). A series of such examples is shown in Figure 1. A well-known historical instance is “The Ambassadors” by Hans Holbein the Younger from 1533, which features a distorted image of a human skull, where its true form is visible from an oblique position to the painting plane. Anamorphosis has also been used in architecture to enhance rooms and make them appear grander, for example in 1895 Andrea Pozzo painted a “false dome" on the flat ceiling of the Church of St Ignatius of Loyola in Rome, to both improve the aesthetics of the interior and save on expenses (Empler, 2017). In recent times anamorphism has evolved and has proven itself useful in more practical applications. It is widely used in sports pitches as a form of advertisement, the angle at which the advert is painted allows the broadcasting camera to see the undistorted image. Examples of anamorphic properties being utilised in 3D environments can be seen in sculpture, where the object only makes sense from one perspective. One such work is Marco Cianfanelli's 2012 sculpture of Nelson Mandela. With photo and image editing techniques now widely available to generate such illusions, this work seeks to explore anamorphism further by identifying and quantifying its use in practical product design contexts (Cowan, 2014).

Figure 1. Examples of anamorphism

1.1 Generating and applying anamorphism

There are two dominant types of anamorphosis, oblique and catoptric. Oblique anamorphosis is where the true undeformed image is only visible from one angle, oblique to the image/object plane (Helal Ayoub, 2015; Stojakovic & Tepavcevic, 2016). Catoptric anamorphosis, sometimes referred to as mirror anamorphosis is where the image is distorted in such a way that its true form can only be seen in the reflection of a curved mirror (Helal Ayoub, 2015). Both types require the observer to be viewing from the “privileged viewing zone” (Kac, 1996), however catoptric illusions require extra equipment for the image to reveal itself and will not be considered in this work.

There are several methods used for the creation of different forms of anamorphism, but most are built on the foundations of the traditional grid method when regarding oblique anamorphoses. This method was developed by Jean Francois Niceron in 1638, found within his book “La perspective curieuse ou magie artificielle des effets merveilleux” (Stojakovic & Tepavcevic, 2016). Figure 2 shows both the distortion grid (left) and the regular formation grid (right). The letters seen along both axes of the regular grid (A-D & A-B) correspond to the matching letters on the distortion grid. Point P is chosen depending on the degree of distortion wanted. The further away from the right-hand side vertical line, bc, the more extreme the image will be distorted. The left-hand side of both grids are equal in length, this helps to maintain image proportion during the transfer. Point P also defines the angle away from

https://doi.org/10.1017/pds.2023.60 Published online by Cambridge University Press

the horizontal of both the top and bottom lines (ab & dc) on the distortion grid. This setup allows each section of the regular grid to be individually focused on and accurately transferred onto the distortion grid, thus create an example of an anamorphic illusion.

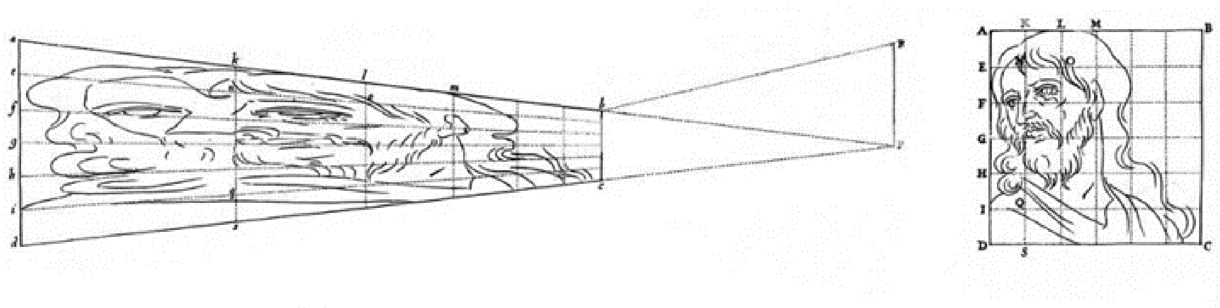

Figure 2. Niceron's grid layout (in Empler, 2017)

There are several accuracy-related problems when using this method – the verticals created from the viewpoint can often be skewed, and inaccuracies of a few centimetres can drastically affect the outcome. Vanishing points are often used for larger outdoor artworks to prevent these issues, however, at a smaller scale, they are more noticeable (Stojakovic & Tepavcevic, 2016). These problems are why many have taken to modern technology to help with the creation of planar anamorphic images. The ability to maintain accuracy when using equipment and various software available not only ensures that the image can be viewed correctly but hugely simplifies the construction process. Popular methods currently used when creating anamorphoses (Empler, 2017) include: photo editing software utilising Niceron's grid method to transform an image to a tapered grid shape; image projection allows it to be traced on irregular surfaces or multiple planes; and 3D modelling software means objects can be distorted and viewed (Empler, 2017; Hansford & Collins, 2007).

Useful and feasible applications of anamorphism in product design, as opposed to just a novelty or interest feature, are limited. The aim of this research was therefore to develop a working knowledge of the phenomenon by exploring where it has been applied and to expand upon this with new areas of implementation. By combining and modifying the ideas voiced in literature, and by iterating and experimenting with these in new settings, the intention was to develop a new concept that would illustrate its usefulness in the design of physical products. In terms of different types of anamorphosis, the possibilities with oblique forms show greater potential within product design. Although catoptric anamorphoses are fascinating they are more illusionary and art-based and require the use of a curved reflective surface – showing less potential for incorporation in practical terms. Creating anamorphoses is not always a straightforward process with many challenges needing to be faced, such as maintaining accuracy during projection, establishing the correct viewpoint and minimising deviation. Regarding the importance of the viewing position, it is surprising that apart from dynamic anamorphism (where the image adapts itself to the changing position of the observer), most anamorphoses require the observer to move into the privileged viewpoint as the object is stationary. Far fewer instances explore manoeuvring the object into the intended position. For example, the object could be rotated, twisted, or tilted by the observer so they can see it in its undeformed structure. This proposes a different form of interactivity and opens the possibility of a new approach to anamorphism. Although dynamic anamorphosis is connected to this, it is still quite different as the 'dynamic' aspect refers to the object or image moving depending on the movements of the observer. With this approach, the movement of the observer will be removed entirely. It will offer the observer more control over the anamorphic object to manipulate as they please, thereby establishing a greater level of engagement and interaction.

2 SECURITY – AN APPLICATION

Damisch (2002) described finding the intended viewpoint of anamorphosis as the reveal of a 'secret object' similar to Kac's (1996) description. Kenaan's (2002) explanation of Holbien's 'Ambassadors' also adopts the word secret into describing the inability to see an anamorphosis. The use of the word secret uncovered a potential function for this new approach to anamorphism within product design:

https://doi.org/10.1017/pds.2023.60 Published online by Cambridge University Press

security. This anamorphic technique could be useful for portable items that contain information regarded as secret to the user. For example, bank cards where the debit card number is illegible unless viewed from an oblique angle through smart geometric design. A similar design could be added to numeric bike locks and padlocks, to prevent thieves from potentially observing the owner's numbers from nearby. An investigation into what distances and angles secret information is visible from would allow designers know the correct measurements to design this form of anamorphism in their products. Further inspiration has come from Ravnik's (2014) experiment looking to improve video call eye contact, altering viewing angles and image distortion.

Using the context of security, therefore, we sought to develop the understanding of anthropomorphism through the creation of anamorphic objects with the ability to conceal information, to assess the features and properties that affect the visibility of such objects, and to characterise these for wider application by designers.

2.1 Creation of the anamorphic objects

It was decided to focus on the theme of numbers, letters, and symbols – concealment of private information, passwords, lock combinations and card details. Most useful information consists of a combination of these characters; therefore, these were an obvious selection for analysis in the experiments. The objects selected contrasted from full works, random assortments of letters and numbers, known logos and geometric shapes. A variety of different objects were selected so that when comparing results, certain features would be highlighted as more apt for concealment.

The approach to creating anamorphic objects involved the use of 2D and 3D design tools to initially stretch and skew the original text into a distorted shape which when seen from the right angle appeared normal, the anamorphic effect. Figure 3 shows the results of transforming the word 'View' by firstly skewing and stretching it (a). This image was imported into a 3D modelling environment so that its outline could be traced and extruded on a base platform, creating 3D characters (b). The next step was to make it harder to read by extruding cuts through the existing letters at various angles (c). This resulted in an object that is less recognisable from above with the slices of material removed, but even with considerably less material, the word 'View' is still visible from the correct viewpoint.

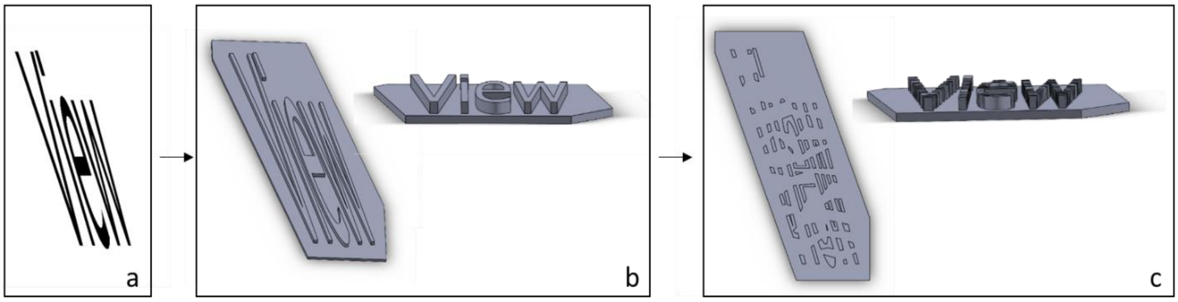

Figure 3. Model CAD creation

A similar approach was followed to create other anamorphic objects, with different directions and degrees of stretching applied. When refining the emerging objects (Figure 4), their characters or symbols were extruded to a uniform height of 8mm to improve the consistency and accuracy of any evaluation. The exception was Object 5, which consisted of a 3D cube where the different edges aligned in the privileged viewpoint. The final creation stage was converting the finished 3D models into real objects. To do this a 3D printer was used which printed the models in white PLA filament. By comparing the two views (plan and privileged viewpoint) of each object, the anamorphic effect can be better understood.

https://doi.org/10.1017/pds.2023.60 Published online by Cambridge University Press

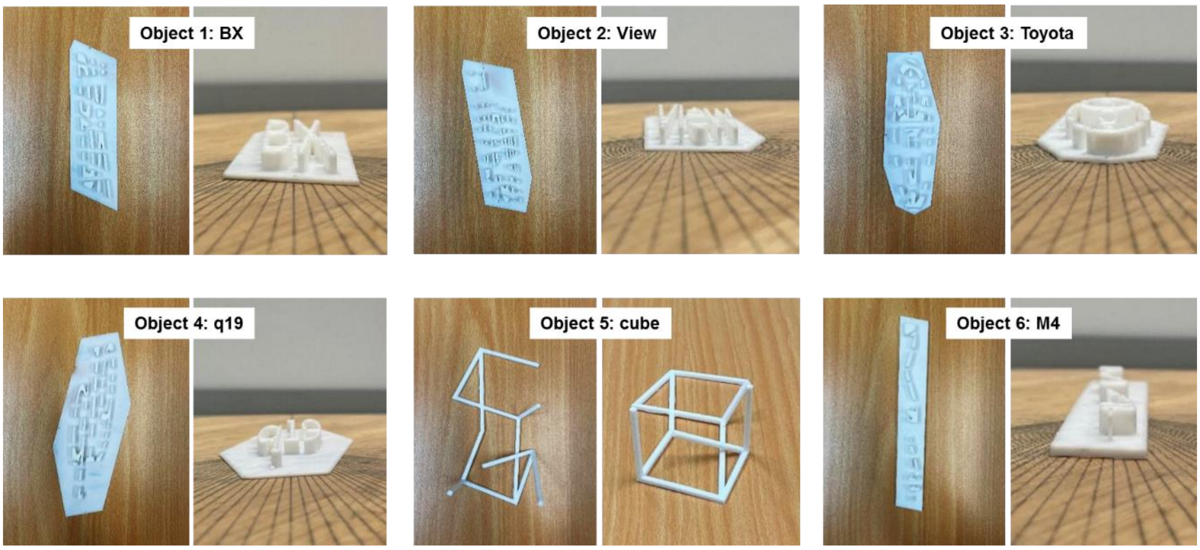

Figure 4. Objects created for study from above and from "privileged viewing zone"

3 EXPERIMENTAL DESIGN

An experiment was designed in order to ascertain the anamorphic effectiveness of the objects through three different tasks relating to time to recognise the object, the angular threshold through which it could be viewed, and how recognisable the object was in normal viewing (Figure 5). 16 participants aged between 21 and 27 conducted the tasks. Each was provided with a handout which explained what anamorphism is (with the help of informative images) and a brief description of its identified potential within product design. They were given the opportunity to ask for clarifications if anything was unclear.

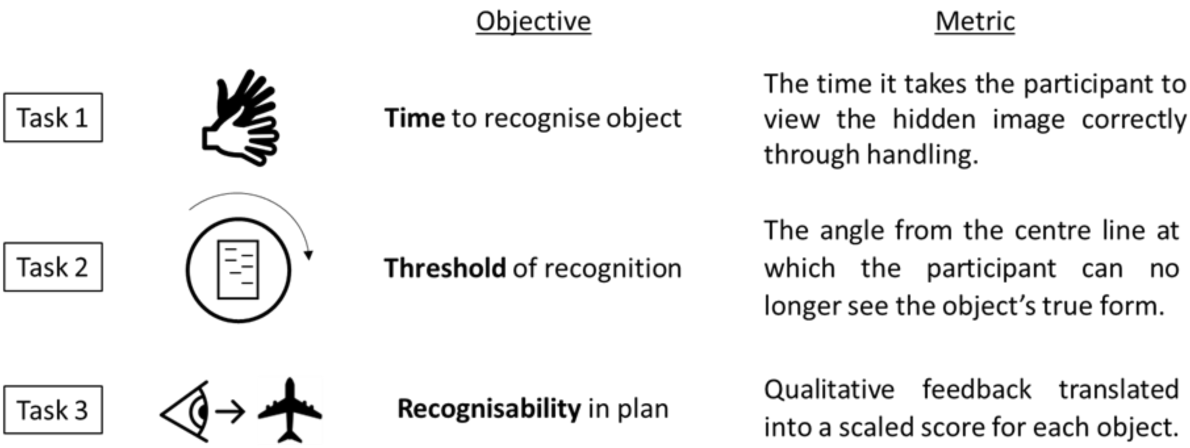

Figure 5. Structure of experimental tasks

3.1 Task 1

The participants were provided with the 3D printed models and invited to handle each individually. They were allowed to interact with the object in any way they wanted, and informed that the different objects would consist of a mixture of letters and numbers, shapes, and logos. They handled each object in turn and were timed until they could find the privileged position and assert what the hidden message was.

3.2 Task 2

The second task involved the use of a 'Lazy Susan' (a rotating tray) that was modified so that the top surface was split up into 2° increments. This was used to identify at what angle each anamorphic object can no longer be seen. Participants were asked to kneel on the ground so that their eye level was just above the top of the rotating tray. Each object was placed in the middle and lined with the centre line. When the user found the privileged viewpoint, they were told to slowly turn the table clockwise until they could no longer

https://doi.org/10.1017/pds.2023.60 Published online by Cambridge University Press

clearly see the hidden image. At this point, the researcher asked them to point at the line there were currently looking down. This line was then measured back to the centre line and the angle was recorded. The same motion was then repeated in the anticlockwise direction and repeated for all objects.

3.3 Task 3

The final task was created to identify which designs were hardest to recognise when looking at them from the top. The purpose of this was to establish which design choices were best at concealing secret information when in more typical in-use viewing positions. The participant was asked to rate how easy it was to identify the hidden message on a scale from 1-10, 1 being very difficult and 10 being easy. This was repeated for all 6 objects, those receiving the lowest average were deemed to be best at concealing information in conventional default modes of viewing and usage.

4 RESULTS AND ANALYSIS

4.1 Time to recognise

The time taken by each participant to find the privileged viewpoint was measured. With these results, a frequency table and frequency plot were created for each object. Firstly, all the results were separated into their appropriate time category, each filling a 10-second interval i.e., 1-10, 11-20 etc. with the frequency determined. This was used to disregard outliers for each object (e.g. Object 1 had two participants that took 90+ seconds to determine the viewpoint, with all others under a minute) and to determine averages times. A frequency plot was then generated, showing that in most cases very few participants took longer than 60 seconds to finally realise the anamorphic object's true form, with 10 cases being over (13 including the outliers).

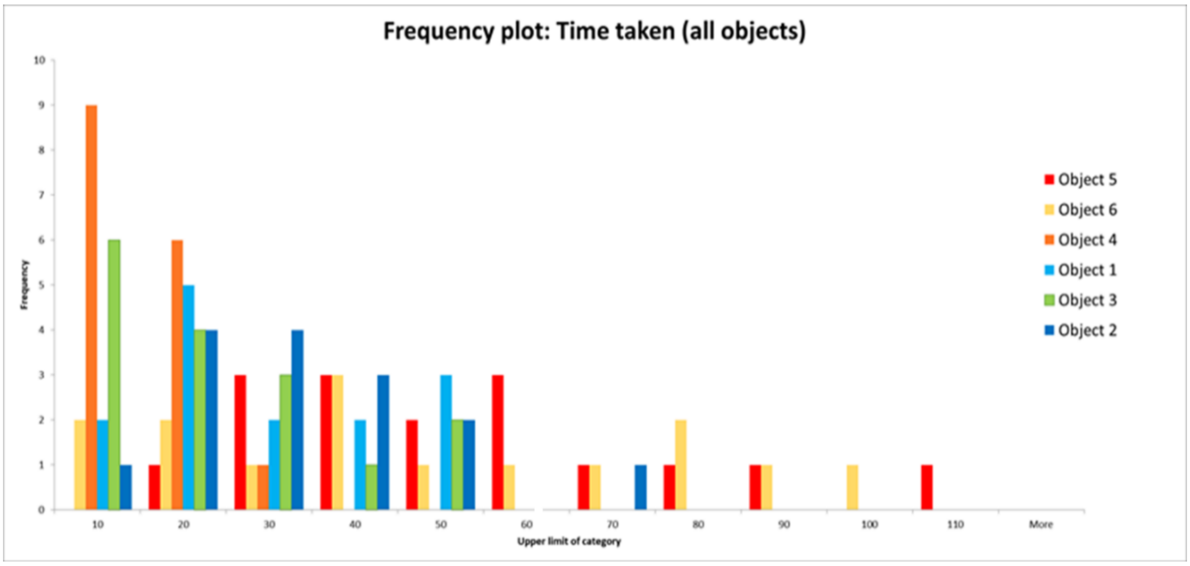

Figure 6. Task 1 overall frequency plot

In reviewing the results Object 5 was found to be most difficult to decipher. With a mean time of 49.4 seconds to find the privileged viewing zone, this was 6 seconds longer from the next closest object. This is perhaps unsurprising when considering its different construction - each cube edge must be aligned to see the true form. Object 6 had the second highest time average at 43.5 seconds. This involved a distinctive type of character distortion, in that the letters and numbers were stretched horizontally instead of vertically as for the other objects. In comparison, there was one anamorphic object which was by far the easiest to interpret: Object 3, the Toyota logo, totalled an average recognition time of 16 seconds. This indicates that either the design was not separated enough, the logo itself wasn't distorted enough, or the logo was easily recognised by all participants.

Throughout the experiment, the participants would interact with the objects differently. Initially, they would rotate the objects in a full 360° motion as they familiarised themselves with the challenge of finding the privileged viewing position. had not yet grasped the premise of an anamorphic object.

https://doi.org/10.1017/pds.2023.60 Published online by Cambridge University Press

Once they had established a sense of the typical object orientation (i.e. the flat base facing downwards), and given that the objects were shown in numerical order, this may assisted in manipulating the object efficiently.

4.2 Threshold of recognition

This analysis aimed to determine which object designs were better at concealing information from different viewpoint angles. Given that participants started from the privileged viewpoint and gradually rotated away, the objects with the smallest unrecognisable angles can be considered the most secure, and their design attributes should be considered for incorporation into products for security purposes. Figure 7 shows the average results for clockwise and anticlockwise rotation for each object.

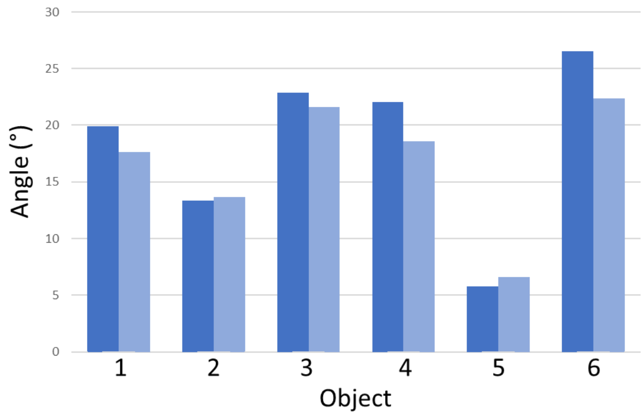

Figure 7. Task 2 results

The object with the smallest angles of unrecognizability was again Object 5, the cube, with a clockwise angle of as little as 5.75°. As with Task 1, this can be attributed to the fact that the geometry is discrete and requires perfect alignment. In other words, the cube frame can only be seen from the "privileged viewing zone", whereas the other objects have a wider range where the secret information can still be identified. Object 3, the Toyota logo, had the second widest angle of visibility which again correlates with Task 1. This can be attributed to its symmetrical form (the logo was only stretched and not skewed), it is a recognisable and well-known logo, and unlike letters and numbers can be viewed from a variety of angles. Object 6, the M4 text, had the widest range of angular visibility. A reason for this could be the fact the message was distorted vertically, as opposed to the horizontal distortion of the other objects, and that vertically stretched text loses its shape, thus recognisability in fewer angle increments

4.3 Recognisability in plan

Task 3's data was gathered to provide further insight into which designs were best at concealing information for potential use in a product. The objects with the lowest scores in this task were the designs that were deemed to have the highest security when being viewed in a casual or passing manner. Figure 8 shows the results gathered during the third task with the average ratings from 16 participants. The easier the object was to recognise, the higher it was scored by the participant.

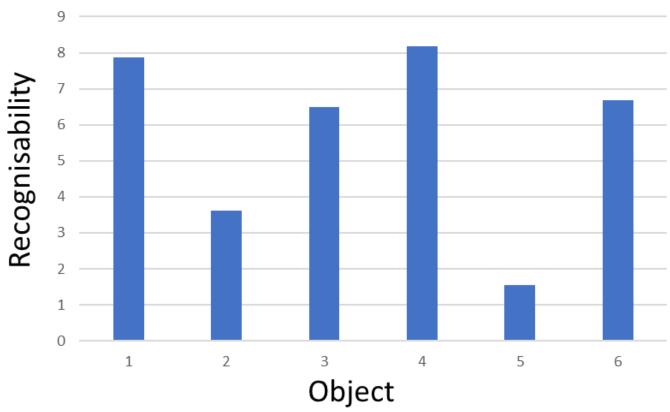

Figure 8. Average recognisability scores for Task 3

https://doi.org/10.1017/pds.2023.60 Published online by Cambridge University Press

In terms of recognisability, Object 5 once again stands out amongst the others: it had the lowest average score at 1.6, with the next closest being Object 2 at 3.6. What became clear is that without prior knowledge of the structure it was impossible to identify unless from an angle very close to the privileged viewing zone. Object 4 was the easiest to identify, which aligns with the fact it was most quickly deciphered in Task 1. Figure 9 compares Object 4 with Object 2, which are comparable in having text-based messages but are most different in terms of score, and picks out some of the identifying features contributing to the difference in their ratings.

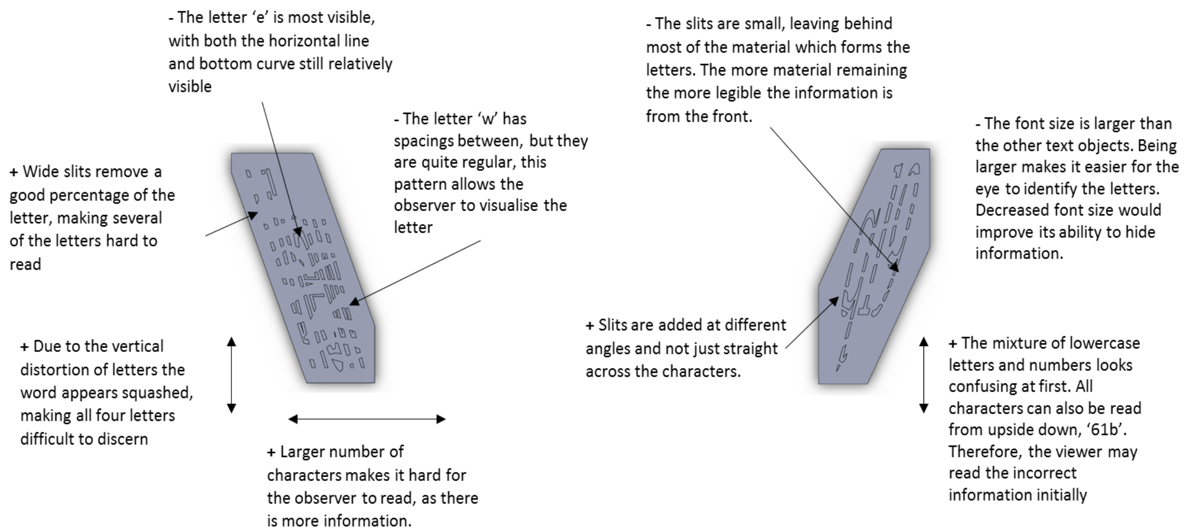

Figure 9. Object feature comparison for Object 2 View (left) and Object 4 q19 (right)

5 DISCUSSION

A gap in research surrounding the use of anamorphism within a product design context divulged itself when exploring dynamic anamorphism and similar descriptions of the intended viewpoint of an anamorphosis as 'Secret' (Damisch, 2002; Kac, 1996). This has inspired a study into whether dynamic anamorphism could be used in a more interactive way, through the user moving an object into its correct position so they can see the hidden information it contains.

Through the creation of several anamorphic objects, it is evident that anamorphism could be used to conceal valuable information such as numbers, letters, logos, and shapes. This could be translated into a range of practical forms for applications such as password protection, bike locks and bank card details. Results showed that Objects 2 & 5 (View and the cube) were the best at concealing the hidden information in different ways. Object 5 required accurate alignment for the cube to be seen and lacked a base plate. With no base plate, it was harder for the observer to know where to position it for the correct view. The base plate on the other objects helped the participants identify a theme for easier viewing, therefore creating designs with no or less of a base plate could improve the information's concealment. Object 2 had thick gaps between segments of the letters, making it harder to interpret because of the lack of material remaining. The word 'View' was also squashed which might have played a part in concealing the information by being harder to read.

The previously mentioned design attributes of Objects 2 and 5 are ones that made the information both harder to see from a front-facing perspective and when rotating the object away from its privileged viewpoint in Task 2. It was also determined that stretching numbers vertically as opposed to horizontally reduced recognisability significantly. This might be because the letters are easier to read when stretched in that direction and regarding Task 2 as the M4 object was rotated it became more recognisable as the letters were in their correct orientation.

Analysing some of the results from all tasks a conclusion was formed that Object 3 was very subjective to the participant. During Task 1 the times were highly varied, and a factor may have been differing levels of awareness of car brands: for those previously unfamiliar with the logo it would have

https://doi.org/10.1017/pds.2023.60 Published online by Cambridge University Press

been less discoverable. Task 3 also saw a wide range in recognition with scores ranging from 3-10. All tasks proved that using this adapted form of dynamic anamorphism is possible and works within a handheld sense. Task 1 particularly showed that the objects created could conceal information and be interacted with as intended. All participants after varying amounts of time could see the object correctly from its intended viewpoint and identified what it was. This shows both effectiveness of the concept and as a security approach to deter thieves etc.

The outcomes of this research have established the potential of anamorphism as a design characteristic rather than just a novelty. To this end, we have generated a set of initial observations around the formulation of the objects that can be generalised and used as design practices that designers should utilise if they want to incorporate anamorphism into their products. By following these, designers will be able to create a secure way of hiding secret information within their products, which could have applications such as preventing information theft, personal security or even within a puzzle.

Table 1. Good and bad practices for creating anamorphic security objects

Good practices	Bad practices
• Thick gaps within letters, numbers, or shapes – less recognisable from face one. • Varying directions of gaps – different angles confuse the eye further. • The less material the harder it is to distinguish from both front-facing and oblique angles. • Minimise the angle of unrecognizability as much as possible – do so by following the previous points. • Vertical distortion compresses the word, making it harder to read from positions that are not the intended viewpoint. • Removing the base material, or making it less obvious where the base is, will make it harder for people to identify the object. • Smaller font size – harder to see/read. • Numbers and letters with lines of symmetry can mislead the observer – for example, a 6 could also be a 9 depending on orientation. • Design objects that require specific alignment, like Object 5 (cube), can only be seen from the privileged viewpoint.	• Stretching the secret information horizontally as opposed to vertically – information is more easily identified as distortion is less severe. • Thin gaps in protrusions –most of the message is still visible to the viewer, too much material. • Regular gaps create a pattern – the eye can recognise the pattern and visually construct the message back together. • Use of large fonts or symbols

In reviewing the findings, there is an argument that the objects created for the experimental part of this paper are extrusions of 2D shapes. The modelling of the objects involved the 2D sketches being vertically extruded and slices of material being removed to create a 3D anamorphic object. However, there are several features which contribute towards the objects being considered as 3D such as protrusion height, radii, spacing etc. The shadows created by physical material added further concealment of the hidden message by distracting the eye at different angles. The 3-dimensional approach to hiding information through anamorphism could also be argued to be less obvious than a flat printed or painted message. To a casual observer, the features offered by product do not suggest a physical function, and therefore offer a discrete method to include information.

Assumptions aside, we would suggest further experimentation with 3D modelling, adding features which would deem the objects more 3-dimensional. For example, the extrusions could be varied across the different sections of the message, requiring all heights to match up from the intended viewpoint. Also, the removal of material from the letters/shapes could be taken from different angles, not just parallel and perpendicular to the baseplate, adding to distortion from different angles.

https://doi.org/10.1017/pds.2023.60 Published online by Cambridge University Press

6 CONCLUSIONS

This paper has described the nature and formulation of anamorphism, and through the generation of a set of 3D objects relating to security, outlined how it could be brought to bear in product design contexts.

In developing the work further, additional studies to systematically address parameters such as skew angles and stretch direction are recommended. Different lighting conditions may have also affected the results, therefore experiments and testing could be conducted in different environments. We have also not considered colour as a factor in the work. The objects created did perform their desired function to varying degrees, and considering how the principles could be viably embodied in practical product forms, such as bike locks or security cards, would further illustrate the potential use of this property.

As well as establishing the practical feasibility of anamorphism in product settings, this work has revealed another in terms of product experience. The user is required to interact and engage with the product before it makes sense, potentially engendering a greater sense of connection with the object in question. Together, we hope these insights will provide a foundation for further work in the creation of anamorphic objects and products.

REFERENCES

Alvaro-Tordesillas, A., Crespo-Aller, S., & Barba, S. (2019). Artalive: An Android Application for Augmented Reality Without Markers, Based on Anamorphic Images. International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives, 42(2/W15), 71–76. https://doi.org/10.5194/isprs-archives-XLII-2-W15-71-2019

Brownie, B. (2013). Modular construction and anamorphosis in Channel 4 idents: Past and present. Journal of Media Practice, 14(2), 93–109. https://doi.org/10.1386/jmpr.14.2.93_1

Cowan, E. J. (2014). 'X-ray Plunge Projection'-Understanding Structural Geology from Grade Data 1.

Čučaković, A., & Paunović, M. (2016). Perspective in Stage Design: An Application of Principles of Anamorphosis in Spatial Visualisation. Nexus Network Journal, 18(3), 743–758. https://doi.org/10.1007/s00004-016-0297-5

Damisch, Hubert. (2002). A theory of /cloud : toward a history of painting. Stanford University Press. https://www.sup.org/books/cite/?id=912

de Comité, F. (2011). A New Kind of Three-Dimensional Anamorphosis. In Architecture. https://www.researchgate.net/publication/272825464

di Paola, F., Pedone, P., Inzerillo, L., & Santagati, C. (2015). Anamorphic Projection: Analogical/Digital Algorithms. Nexus Network Journal, 17(1), 253–285. https://doi.org/10.1007/s00004-014-0225-5

Empler, T. (2017). Anamorphosis and Contemporaneity. Design Journal, 20(sup1), S2858–S2872. https://doi.org/10.1080/14606925.2017.1352797

Gregory, R. (1968). Perceptual illusions and brain models. Proceedings of the Royal Society of London. Series B. Biological Sciences, 171(1024), 279–296. https://doi.org/10.1098/rspb.1968.0071

Hansford, D., & Collins, D. (2007). Anamorphic 3D geometry. Computing (Vienna/New York), 79(2–4), 211–223. https://doi.org/10.1007/s00607-006-0199-6

Helal Ayoub, M. (2015). A simplified procedure for anamorphic sculpture. In International Design Journal (Vol. 5, Issue 2).

Hunt, J. L., & MacKay, A. H. (2011). Designing a human-scale cylindrical-mirror anamorphosis for an outdoor art installation. Journal of Mathematics and the Arts, 5(1), 1–16. https://doi.org/10.1080/17513472.2010.501422

Kac, E. (1996). Key Concepts of Holopoetry. Experimental — Visual — Concrete (pp. 247–257). Brill. https://doi.org/https://doi.org/10.1163/9789004449374_026

Kenaan, H. (2002). The "Unusual Character" of Holbein's 'Ambassadors.' https://www.jstor.org/stable/1483697

MacKenzie, K., & Wodehouse, A. (2021). Translating 2D geometric illusions for 3d contexts (1). IJACDT Vol.10.

Ravnik, R., Batagelj, B., Kverh, B., & Solina, F. (2014). Dynamic anamorphosis as a special, computer-generated user interface. Interacting with Computers, 26(1), 46–62. https://doi.org/10.1093/iwc/iwt027

Sánchez-Reyes, J., & Chacón, J. M. (2020). How to make impossible objects possible: Anamorphic deformation of textured NURBS. Computer Aided Geometric Design, 78. https://doi.org/10.1016/j.cagd.2020.101826

Stojakovic, V., & Tepavcevic, B. (2016). Distortion Minimization: A Framework for the Design of Plane Geometric Anamorphosis. Nexus Network Journal, 18(3), 759–777. https://doi.org/10.1007/s00004-016-0302-z