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Design heuristics for artificial intelligence: inspirational design stimuli for supporting UX designers in generating AI-powered ideas

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https://doi.org/10.1145/3411763.3451727

PUBLISHER

ACM

VERSION

AM (Accepted Manuscript)

PUBLISHER STATEMENT

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REPOSITORY RECORD

Jin, Xiaoneng, Mark Evans, Hua Dong, and Anqi Yao. 2021. “Design Heuristics for Artificial Intelligence: Inspirational Design Stimuli for Supporting UX Designers in Generating Ai-powered Ideas”. Loughborough University. https://hdl.handle.net/2134/14241983.v1.

Design Heuristics for Artificial Intelligence: Inspirational Design Stimuli for Supporting UX Designers in Generating AI-Powered Ideas

Accepted for 2021 ACM CHI Virtual Conference on Human Factors in Computing Systems 8 – 13 May 2021 Yokohama Japan (Virtual)

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Artificial Intelligence (AI) will provide novel User Experience (UX) solutions if UX designers understand how AI can be best utilized. They need to understand AI capabilities and envisage potential applications. To aid the ideation processes, design heuristics for AI are needed to support UX designers in the conceptual design stage. Forty design heuristics were extracted from 1,755 granted AI patents through a four-step process. The feasibility of the heuristics was verified with two AI-powered case studies: a smart canteen and an online smart shopping system. Case studies suggest that AI design heuristics can be used as design stimuli in the early conceptual design phase to support practitioners in exploring a larger design space for the generation of AI-powered ideas.

CCS CONCEPTS: • Human-centered computing → Interaction design →Interaction design process and methods

Additional Keywords and Phrases: Artificial intelligence; Design heuristics; UX design; Creativity; Design tools

1 Introduction

Artificial Intelligence (AI) can enhance life in a number of fields e.g., transportation, home/service robots, healthcare, education, public safety and security [62]. AI is a foundational technology that can boost competitiveness, increase productivity, protect national security and help resolve societal challenges [17]. These unique features/capabilities have been identified by designers with interest in incorporating the advantages of AI in their designs [18, 71]. However, research suggests that practitioners are challenged in their understanding of AI capabilities and capacity to envisage novel and implementable solutions for a given UX problem [18, 72].

To support practitioners, AI tools, methods and aids [15, 3, 26, 74] have been developed. Unfortunately, these methods predominately support the later phases of the design process (*i.e. the evaluation phase*). Few studies have been conducted to explore ways in which practitioners might generate a greater number of novel and diverse concepts for the AI domain in the early conceptual design phase.

The ability to take a problem and generate multiple, varied solutions that can lead to new creative outcomes is often referred to as concept generation or ideation [59]. Ideation originally determines the type of design and plays an important role in the development of novel concepts and, ultimately, potential for business success [30]. Generating a diverse range of ideas can be challenging as designers become *'fixated'* whereby attention becomes focused on a single past example or one new idea [34, 66]. UX practitioners meet *design fixation* challenges in generating AI-powered ideas beyond *automation, recommenders, and reminders* [71].

In an attempt to increase concept generation for AI enabled UX concepts our research question is: How might practitioners be supported in understanding the potential of AI to facilitate the generation of novel and diverse concepts in the early conceptual design phase?

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This paper focuses on developing 'creative tools' for AI. Creative tools are required to aid the designer to produce more 'creative' ideas in short periods [30]. 'Design heuristics (DHS)' are a cognitive 'shortcuts' that point toward useful design patterns to reduce search time [23]. DHS as a tool can help boost creativity in the early conceptual design phases [73]. DHS has not only been developed to support general design tools (e.g., TRIZ[24], SCAMPER[19], DHS77[73]) but also were developed for specific fields (e.g., DHS for additive manufacturing, DHS for digital design) [10, 35]. AI is becoming a key technology to benefit many areas [62] however, there are no design heuristics for AI applications.

The aim of this study is to systematically analyze AI-related applications and technologies based on granted patent documents from 2008 to 2020 and propose Design Heuristics for AI (AIDHs). Our study contributes to the lack of existing knowledge of DHS in the digital era [36] through three main contributions: 1) development of the tool 40 AI DHS by systematically analyzing 1,755 granted patents in AI domain; 2) a proposal of a new method based on structural big data for extracting DHS; 3) taking AI from uncanny to explainable to support design ideation.

2 Background

2.1 Artificial Intelligence as new design material

Technology tends to evolve from an elite niche to a mainstream tool and AI is undergoing a similar transformation [44]. AI has realized as a new design opportunity in recent years, especially in the UX domain [18, 71]. Whilst AI emerged in the 1950's, there has been increasing interest with increases in data and computing power [7] and can contribute to a broad number of fields e.g., transportation, home/service robots, healthcare, education, public safety and security, etc [62]. AI technology is now becoming *mature* and *accessible* and as we enter what has been identified as the age of deployed AI [44]. The key issue is no longer how AI technology works, but what useful work it can do [44].

2.2 Challenges for designing AI applications

Yang et al. [72] explored why AI is uniquely difficult to design for i.e. it is difficult to articulate what AI can/cannot do. There are challenges in understanding AI and its capabilities in not knowing how to purposefully use AI for the design problem at hand [18]. Designers' understanding of AI is limited, making it difficult to ideate, sketch, and prototype AI concepts [18]. Generating a diverse range of ideas is challenging as designers can become *'fixated'* [34, 66]. Despite the emphasis on creative exploration, designers have been shown to experience limitations when attempting to generate diverse concepts [14]. For example, practitioners meet *design fixation* challenges in generating AI-powered ideas beyond *automation, recommenders, and reminders* [71].

2.3 Existing AI design tools

Developing tools and aids for supporting design for AI has become a popular topic over recent years. Google developed AI guidance for practitioners [26]; Amershi et al. [3] developed *18 guidelines* for Human-AI Interaction; Corbett et al. [15] propose 'Interactive Machine Learning Heuristics Evaluation'; and Zhou et al. [74] put forward a design method called Material Lifecycle Thinking (MLT) that considers ML as a design material with its entire lifecycle. However, these methods are predominately useful in the later phase of the development process. There are a lack of tools to support AI-powered UX design in the early conceptual design phase where practitioners face challenges in understanding AI capabilities and imagining novel AI solutions for given UX issues [72]. Ideation determines the type of design and plays an important role in the development of novel concepts and business success [30]. However, few studies have been conducted to support practitioners in the generation of novel and diverse concepts for the AI domain in the conceptual design phase.

2.4 Analogical reasoning and design heuristics in design research

Analogical reasoning is the process by which information from a source is applied to a target through the connection of relationships or representations [25, 45]. Design researchers have demonstrated that analogies can help promote the generation of additional solutions, or solutions with positive characteristics such as novelty [40, 22, 48]. Design Heuristics (DHS) are a context-dependent directive based on intuition, tacit knowledge or experiential understanding which provides design process direction to increase the chances of reaching a satisfactory, but not necessarily optimal, solution [23]. DHS are evidenced to help generate ideas effectively in the conceptual design phase and play an important role in addressing issues of design fixation [73]. Howard [29] suggests that design tools can be categorized as three domains - creative-analysis tools, thinking tools, stimuli tools with DHS being categorized as a *stimuli tool*. Different DHS have been developed for different purposes, such as DHS for additive manufacturing [10], DHS for assistive (one-handed) products [32] and DHS for digital design [35]. Support of DHS for AI is limited.

2.5 Patent datasets

Patent documents are a rich source of technological and commercial information and represent a comprehensive research resource [56]. Patent must be both useful and novel [48] and, as such, have been considered sources of analogies and concepts that can lead to

innovative solutions [48]. TRIZ [33], a widely used DHS for Engineering Innovation, is also based on patent abstract analysis. This inspired us to look at existing AI patents available in English and Chinese, with the scope limited by the authors' language skills. It was found that there has been a steady increase in the numbers of granted AI patents in America, Europe and China since 2008. Interestingly, in 2019 the figures suggest a dramatic increase. The data indicates that AI technology applications are becoming mature and that this technology will enter a high-speed development period in the near future. The large number of granted patents provides an opportunity to extract DHS through patent-based analysis which is a common method to investigate modern technology dynamics and recent trends in scientific development [31].

2.6 Research opportunity

Although tools, methods and aids for designing AI have been proposed [15, 3, 26, 74], few design stimuli tools were developed for AI, especially in the design heuristics domain. Technical advances have triggered an opportunity for design innovation to generate a wealth of new products [18]. A challenges for designing AI [72] are the limited timely innovations in AI applications. Design has the capacity to engage in the innovation processes in AI applications as the design discipline is adept in discovering users' actual needs and generating creative solutions through design thinking/methods [16]. Tools and techniques are needed to support practitioners in generating diverse and innovative AI-powered ideas. By analyzing AI-related patents, a series of AIDHs can be extracted to meet the needs of the fast-developing digital era [24].

3 Research Methods

To develop a design stimuli tool (Design Heuristic) with a focus on AI, a four-step process was adopted as identified in in Figure 1.

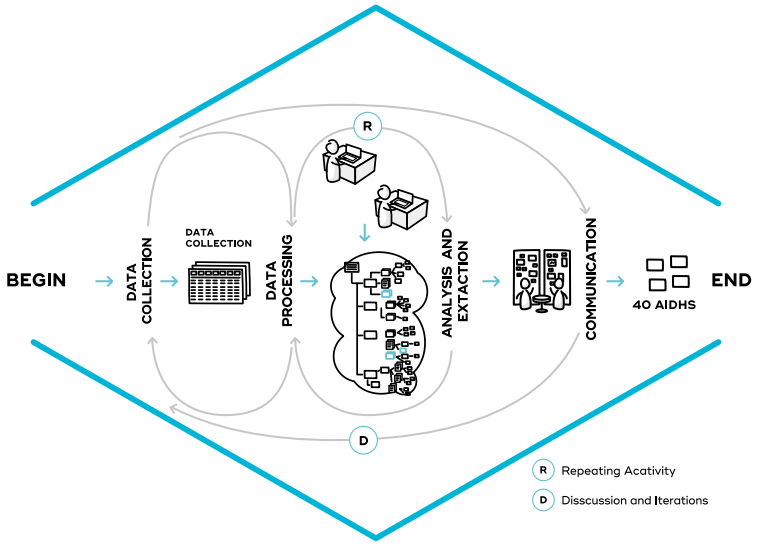


Figure 1 The framework of extracting design heuristics.

3.1 Phase 1: Data collection

The patent data was collected from *Derwent Innovation*, the world's most comprehensive database of enhanced patent information (https://www.derwentinnovation.com/login/) and exported to Microsoft Excel files for further analysis. Table 1 shows the search strategy. To extract highly innovative DHS, the patents of the *Utility Model* and *Pending Patents* were excluded. Only patents from the United States, China and the Europe were included as these countries and regions lead AI technology and marketing and English and Chinese were accessible languages to the authors. 'Artificial Intelligence' was used as the keyword in searching the Title/Abstract of all patent documents. The publication dates included the period from 1st January 2008 to 1st January 2020. In total, 2,062 *granted patents* from Derwent Innovation were included. In the Microsoft Excel file, data was organized as Patent Name, Patent Title, Abstract, and Assignee/Applicant. Further filtering (e.g. eliminating 'dead' and indeterminate patents) results in ***1,755 patents***.

Table 1 Search Strategy

Search Strategy	Patent Collections
TAB=(artificial intelligence) AND DP>=(20080101) AND DP<=(20200101);	Collection: DWPI, CN Grant, EP Grant, US Grant (Applications and Utility Models are excluded)

(TAB=Title/Abstract; DP=Publication Date)	CN=China, EP=Europe, US=United States
Record(s) found out	2,062
Filtering the Alive patents	1,755 (Application Language: EN, ZH)
(Dead and Indeterminate are excluded)	EN=English, ZH=Chinese

3.2 Phase 2: Data processing

The Word Frequency was utilized which was computed (including stemmed words) using QSR NVivo 12® [8, 20]. The word frequency was exported to a Microsoft Word file for further analysis.

3.3 Phase 3: Analysis and extraction

Two researchers undertook the data extraction processes with each analyzing and extracting the AI design heuristics individually.

1. **Analyzing high-frequency words**. By reviewing every *high-frequency word* that appeared in more than three patent titles individually, the two researchers selected words independently and highlighted them in Microsoft Word. In this phase, 46 potential words were identified as the initial Design heuristics (DHS). Appendix A.1 shows preliminary DHS extraction based on the Word Frequency and the researchers' analysis.
2. **Contrasting the details of patent documents and potential AIDHs**. 46 potential DHS nodes were created by QSR NVivo 12® after which the researchers utilized every potential DHS as a keyword to track the patent title for further contrasting. Every tracked patents' title was then reviewed to identify if these patents were highly relevant to the potential DHS and the patent's title added to the DHS node one by one.
3. **Confirming the AI Design Heuristics**. If more than three patent examples shared key functions and features, design heuristics were confirmed based on these node groups.

3.4 Phase 4: Communication

In this phase, the two researchers entered discussions to reach a consensus. For example, some DHS were similar such as analyzing and analysis, automated and automatic, decision and determining, identification and identifying/recognition, and prediction/forecasting so these were combined.

4 Results

Table 2 shows the list of extracted design heuristics for AI accompanied by examples and divided into thematic categories. The AI design heuristics were general (i.e. ***Analogical Reasoning***) so that the imagination and creativity of designers would not be constrained by excessive detail [24]. To make the design heuristics as easy to understand and remember as possible, 40 AIDHS are organized via four categories - decision making, personalization, productivity, security.

Table 2 Extracted design heuristics for AI accompanied by examples and divided into thematic categories

No.	DHS	Examples (Title)
A	**DECISION MAKING**	
1	Analyzing	Artificial intelligence based vehicle dashboard analysis [4]
2	Determining	Method for determining acceptability of proposed color solution using an artificial intelligence model [43]
3	Diagnosis	Artificial intelligence-based system and methods for corneal diagnosis [1]
4	Evaluation	A video evaluation recommendation system [27]
5	Judging	Based on artificial intelligence of the intelligent robot of multi-sound source judging method and device [70]
6	Mapping	Proactive telephone number mapping configuration management [38]
7	Planning	Robotic capability model for artificial intelligence assisted manufacturing supply chain planning [37]
8	Forecasting	Systems and methods for forecasting client needs using interactive communication [55]
9	Simulation	Method and apparatus for creating a computer simulation of an actor [53]
10	Recognition	Medical image identification and interpretation [60]
B	**PERSONALIZATION**	
11	Adaptive	Adaptive real-time conversational systems and methods [12]
12	Customization	Client-server hybrid AI scores for customized actions [67]
13	Dynamic	Dynamically manipulating an emoticon or avatar [13]
14	Learning	Self learning method and system for managing a group reward system [50]
15	Natural	Natural interactive user interface using artificial intelligence and freeform input [28]
16	Notification	Artificial intelligence for resolution and notification of a fault detected by information technology fault monitoring [46]
17	Interaction	Natural interactive user interface using artificial intelligence and freeform input [28]
18	Personalizing	Method for personalizing chat bots [69]
19	Recommending	Method and system for video and film recommendation [11]

20	Real Time	Method and system for real time visualization of individual health condition on a mobile device [54]
C	**PRODUCTIVITY**	
21	Automation	Systems and methods for automatically measuring a video game difficulty [2]
22	Autonomous	Autonomous information technology diagnostic checks [9]
23	Assisted	Artificial intelligence assisted tagging of users in digital media online [21]
24	Classification	Classification technique for multi-band raster data for sorting and processing of colorized data for display [57]
25	Communication	Methods and apparatus for performing machine learning to improve capabilities of an artificial intelligence (AI) entity used for online communications [68]
26	Detection	Mood detection with intelligence agents [6]
27	Extraction	Utilizing artificial intelligence for data extraction [42]
28	Generation	System and method for automatic generation of user-oriented homepage [65]
29	Managing	Digital healthcare information management [58]
30	Manipulating	Dynamically manipulating an emoticon or avatar [13]
31	Measuring	Systems and methods for automatically measuring a video game difficulty [2]
32	Optimizing	Machine-learning systems and techniques to optimize teleoperation and/or planner decisions [39]
33	Reconstruction	iRecon: intelligent image reconstruction system with anticipatory execution [64]
34	Regulating	Regulating the growth of complexity in developmental systems [61]
35	Scheduling	Computerized system and method for distributed energy resource scheduling [51]
36	Testing	Utilizing artificial intelligence to test cloud applications [63]
D	**SECURITY**	
37	Warning	Motor vehicle artificial intelligence expert system dangerous driving warning and control system and method [52]
38	Monitoring	Monitoring social media for specific issues [47]
39	Security	Method, system, and computer program product for assessing information security [5]
40	Tracking	Systems and methods for tracking motion and gesture of heads and eyes [49]

5 Case Studies

Two case studies were employed to explore the feasibility of the design heuristics - a smart canteen and a smart online shopping system. The smart canteen can be seen as a design brief for digital innovation and the smart online shopping system can be seen as a UX design brief. A novice UX designer was invited to attend the preliminary evaluation study and was asked to generate as many concepts as possible within 20 minutes by utilizing AIDHS 40 including ***Analogical* words** and related AI ***examples*** (see Table 2) for each pre-defined design brief. The UX designer was provided extra 15 minutes for writing textual descriptions on each design brief for further analysis.

The case studies were performed by the first author and are original designs to illustrate the heuristics, i.e. they are not based on other case studies or specific existing products. Below are the ideas proposed by the UX designer, using different AIDHS. Two design works are described below with the DHS utilized numbers identified in brackets by #).

5.1 Case study: Smart Canteen

Decision Making. The 'Smart Canteen' can analyze (#1 *Analyzing*), judge (#5 *Judging*) and forecast (#8 *Forecasting*) the peak-hour real-time by monitoring the canteen's environment (#20 *Real-time*; #38 *Monitoring*). It can give notifications to potential customers for helping them to avoid the peak-hour, thus reducing the waiting time. The 'Smart Canteen' can also help chefs to determine whether they need to cook more dishes (#2 *Determining*), potentially reducing the waste of food. AI-based shopping satisfaction evaluation (#4 *Evaluation*) can be achieved by detecting users' facial moods (#26 *Detection*). Additional concepts include 'mapping the most favorite dishes smartly' (#06 *Mapping*), and 'recognizing the dishes for helping staff to calculate the bills productively' (#10 *Recognition*).

Personalization. The 'Smart Canteen' provides personalized functions for meeting users' needs. The App for 'Smart Canteen' can recommend dishes to the customer based on their shopping histories (#19 *Recommending*). Customers can interact with smart robots for ordering (#17 *Interaction*), (e.g., multilingual communication supports).

Productivity. Prices are generated and managed smartly based on AI (#28 *Generation*, #29 *Managing*) (i.e. dynamic price generation based on the dynamic costs and time factors, etc) (#13 *Dynamic*). Optimizing the dishes' making process intelligently (#32 *Optimizing*), such as scheduling the dishes marking material procurement smartly (#35 *Scheduling*).

Security. Comprehensive management for food security based on AI. For example, monitoring the whole process of raw material for food safety (#38 *Monitoring*; #39 *Security*) and food traceability (#40 *Tracing*). When ordered dishes are lacking in the canteen, the AI will give warnings (#37 *Warning*).

5.2 Case study: Smart Online Shopping System

Decision Making. AI will assist the customer to evaluate the goods/products comprehensively (#4 *Evaluation; #23 Assisted*) and judge the products' quality (i.e. if it is a fake or low-quality product) (#5 *Judging*). The 'Smart Online Shopping System' can analyze the customer's shopping habits automatically (#1 *Analyzing; #21 Automation*) for helping the customer to determine which one is more suitable (#2 *Determining*). The 'Smart Online Shopping System' offers 3D simulation service for augmented reality (#9 *Simulation*) (e.g. customers can see the fitting effects based on their body size and the type of clothes).

Personalization. Adaptive user interface (UI) (#11 *Adaptive*) for enhancing UX based on different platforms (i.e. Smartphone, laptop, and PC). Dynamic product information recommendations for customers (#13 *Dynamic*; #19 *Recommending*). The system will give the

customer notifications (#16 *Notification*) on Sales and new season products. Natural and interactive customer service assistant, i.e. voice communication for order customers and gesture communication for deaf and hard-of-hearing customers (#15 *Natural*; #17 *Interactive*; #25 *Communication*). The 'smart system' offers personalized/interesting products recommendation to different customers (#18 *Personalization*; #19 *Recommending*).

Productivity. It also offers the function of key information extraction based on the users' customized definition (#27 *Extraction*; #12 *Customization*). Smart video generation is based on sorting out goods' pictures and texts for improving users' understanding and attention (#28 *Generation*). Managing the 'shopping cart' or 'collection' system intelligently (i.e. combining similar goods in the same category for managing and classifying productivity) (#29 *Managing*; #24 *Classification*). Optimizing the display of goods' images and textual descriptions by AI for improving users' understanding and attention (#32 *Optimizing*). The user interface of the shopping system can differ for different customers (e.g. larger textual display for older customers).

Security. 'Smart Online Shopping System' also offers functions for security such as monitoring the whole process of shopping (#38 *Monitoring*; #39 *Security*) and risk traceability (#40 *Tracing*). Pre-warning will be given when critical issues are detected for risk management and control (#37 *Warning*; 26# *Detection*).

6 Discussion

6.1 Contributions and implications

6.1.1 40 Design Heuristics for AI.

Through analyzing 1,755 AI patents (from 2008-2020) granted in the US, China and the Europe (US, CN, EP) based on a *four-step analysis method*, forty AIDHS were extracted. They were initially evaluated through two case studies. In the case of the smart canteen, 12 ideas were generated and 20 unique heuristics employed. In the case of the smart online shopping system, 15 ideas were generated and 25 unique heuristics employed. Between the two case studies, 31 out of 40 heuristics were utilized. Interestingly, 56% of ideas employed multiple DHS (≥ 2) (e.g. case study 1: 6 out of 12; case study 2: 9 out of 15). The high usage rate of DHS indicates that the AIDHS tool is easy to understand and employ. The 40 AIDHS have the potential to be a design stimuli tool in the early conceptual design phase for helping practitioners to explore a larger design space and generate more AI-powered ideas. More ideas will feed higher quality ideas.

6.1.2 A New Method for Design Heuristics Extraction.

Designers face many challenges. For example, they have to learn new knowledge and skills for emerging technologies because new technologies can support designers in the generation of more innovative products [41]. In this paper, we propose a new method for extracting DHS (i.e., **Inspirational Design Stimuli**) for emerging technologies. The AIDHS will aid practitioners in the ideation stage.

6.2 Limitations and future work

AIDHS can help practitioners to generate more AI-powered ideas by opening-up a wider design space when utilizing one or multiple DHS simultaneously. In the later design phase, these concepts may need to be further discussed with AI algorithm scientists/engineers for evaluating technical feasibilities or to reference AI design guidelines for aiding evaluation [3]. These extracted DHS are based on the current state of AI which is a fast-developing technology. Different application scenarios may stimulate new innovations over time.

Future research is needed to validate the effectiveness by utilizing varied metrics for further evaluation (i.e. diversity, usefulness, novelty, and creativity) through a controlled experiment. Future user studies with both novice and expert designers need to be conducted to explore the applicability of the method.

7 Conclusion

We have extracted 40 design heuristics for AI through studying 1,755 granted AI patents. The feasibility of the heuristics was preliminarily tested using two AI-powered design briefs - a smart canteen and an online smart shopping system. Results suggest that the 40 AI design heuristics have the potential to support concept generation in the early design phase. AIDHS has proved effective in aiding a novice UX designer in generating large numbers of innovative ideas during the early conceptual design phase. The originality of our study is twofold: 1) we have used a new method to extract design heuristics for AI. 2) we have developed the novel tool AIDHS which can support ideation.

Overall, our study suggests that AIDHS can be employed as a design stimuli tool for ideation. It can help practitioners to explore a larger design space for generating AI-powered ideas, with reduced design fixation [34, 66].

ACKNOWLEDGMENTS

This research is supported by **China Scholarship Council** (Grant no: 201906360310).

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A APPENDICES

A.1 Preliminary DHS Extraction Based on the Word Frequency and researchers' analysis

LEARNING	76	SIMULATION	44	AUTONOMOUS	29	IDENTIFYING	21	SCHEDULING	5
MANAGING	70	RECOGNITION	43	PREDICTION	29	MEASURING	17	WARNING	5
ANALYSIS	65	MONITORING	42	ADAPTIVE	27	PLANS	17	JUDGING	3
DETECTION	59	DIAGNOSIS	38	NATURAL	25	NOTIFICATION	16	MANIPULATING	3
COMMUNICATION	54	AUTOMATED	37	TRACKING	24	ANALYZING	14	RECONSTRUCTION	3
INTERACTIVE	52	SECURITY	33	CLASSIFICATION	23	FORECASTING	14	REGULATING	3
AUTOMATIC	47	IDENTIFICATION	31	TESTING	23	EVALUATION	12		
DYNAMIC	46	DETERMINING	30	CONFIGURING	22	CUSTOMIZED	11		
GENERATION	46	PERSONALIZING	30	DECISION	22	MAPPING	11		
OPTIMIZING	45	ASSISTED	29	RECOMMENDING	22	EXTRACTION	7		