

**Preattentive Visual Processing:
A Design Evaluation of the IRS 1040 Tax Return Form**

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DESIGN EVALUATION OF IRS 1040 TAX RETURN FORM

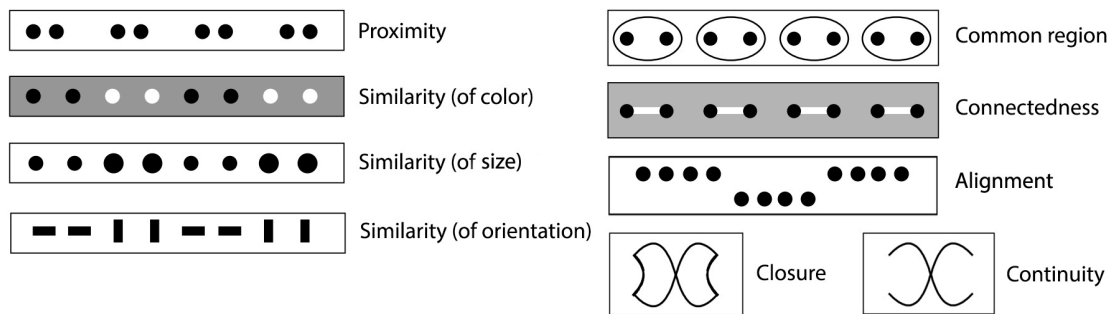
Introduction

Humans are, by nature, pattern seekers (Whitson & Galinsky, 2008). In order to efficiently process and order the mass of sensory information continually flooding the visual system, humans intrinsically seek to identify and group stimuli with shared perceptual and spatial features (Frisby & Stone, 2010). Among these features, researchers have identified a select group that the low-level visual system is capable of rapidly and accurately detecting (Quinlan & Humphreys, 1987). These “preattentive” features are coded independently, and in parallel, by the low-level visual system, yielding separate feature maps, which are later integrated and used in object recognition (Treisman & Gelade, 1980; Quinlan & Humphreys, 1987; Vecera & Gilds, 1998).

Though coined “preattentive features,” due to the early belief that their detection preceded focused attention, subsequent research demands a more nuanced interpretation of the term; one in which the distinction between unconscious and conscious attention is more fluid and less concrete (Neisser, 1967; Callaghan, 1989; Wolfe, 1994). Despite the debate, there is a general consensus that certain preattentive grouping principles, including proximity, alignment, common region, and connectedness (see Figure 1), facilitate rapid visual processing (Kubovy and Wagemans, 1995; Beck, Rosenfeld, and Ivry, 1989; Beck & Palmer, 2002; Palmer & Rock, 1994; Palmer, Brooks, and Nelson, 2003)

Figure 1

Common preattentive grouping principles (Source: Palmer, Brooks, and Nelson, 2003)



When these grouping principles are properly applied in visual design, the user can instantly and effortlessly gain a sense of primitive structure and organization (Palmer, Brooks, and Nelson, 2003). However, when disregarded or misapplied, the user is forced to deploy directed attention to what should otherwise be an effortless perceptual process, resulting in anxiety, inefficiency, and unnecessary cognitive load (Treisman & Gelade, 1980; Healey, Booth, and Enns, 1996; Whitson & Galinsky, 2008).

This paper will review the neurological and psychophysical basis for preattentive processing, with a focus on the preattentive grouping principles of proximity, alignment, connectedness, and

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common region. These principles will then be applied to a design evaluation of the IRS 1040 tax return form (see Figure 2).

Figure 2
IRS 1040 Tax Form

The image displays two pages of the IRS 1040 tax return form for the year 2013. Page 1 (left) contains the header with 'Form 1040', 'Department of the Treasury - Internal Revenue Service', and 'U.S. Individual Income Tax Return 2013'. It includes fields for the taxpayer's name, address, and filing status (Single, Married, Head of Household, etc.). The 'Exemptions' section allows for claiming dependents. The 'Income' section lists various sources of income such as wages, dividends, and capital gains. The 'Adjusted Gross Income' section lists deductions like educator expenses, health savings account, and moving expenses. Page 2 (right) continues the form with 'Tax and Credits' (including standard deduction, itemized deductions, and credits like child tax credit), 'Other Taxes' (such as self-employment tax and additional taxes on IRAs), 'Payments' (federal income tax withheld, estimated tax payments), and 'Refund' (amount of refund). The bottom of both pages includes a 'Sign Here' section for the taxpayer and preparer, and a 'Paid Preparer Use Only' section.

Early Visual Processing

Any discussion of visual processing begins, first and foremost, with the eye. The act of seeing involves a continuous cycle of eye movement followed by the perception and interpretation of visual stimuli (Stone, 2012). Since preattentive processing is believed to occur rapidly and unconsciously, this paper will focus on the early visual processes that occur within the first 200msec of stimuli presentation, the time before which the brain is incapable of initiating eye movement (Healey et al., 1996).

Vision is initiated when light enters the eye and is refracted and focused onto the retina (Stone, 2012). The retina contains millions of photoreceptors which first transform and then send visual information to the retinal ganglion cells (Frisby & Stone, 2010). The retinal ganglion cells respond to specific patterns of light hitting their receptive fields, converting these signals into red-green, yellow-blue, and dark-light differences (Ware, 2013).

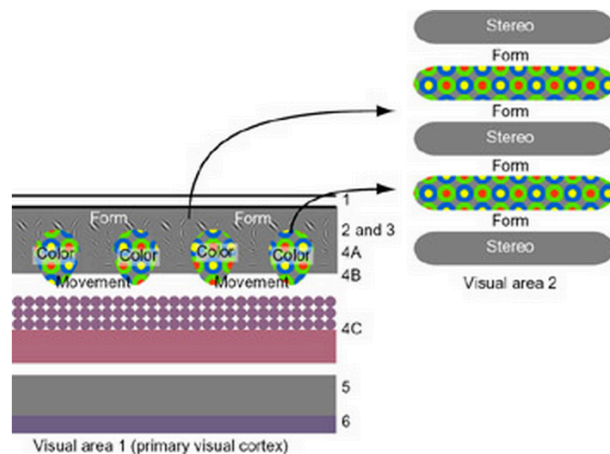
Following this initial processing in the retina, the signal travels to the visual cortex via the optic nerve (Stone, 2012). Before reaching the visual cortex, however, the signal passes through the lateral geniculate nucleus (LGN) (Stone, 2012). The LGN serves as a relay station, separating the retinal input into parallel streams—one containing color and fine structure, the other containing

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contrast and motion—before it arrives in the primary visual cortex (V1) and extrastriate visual cortical area (V2) (Frisby & Stone, 2010). It is here that the majority of visual processing takes place (Lennie, 1998). As in the retina, cells in V1 and V2 have distinctive receptive fields, which respond to particular patterns of light, such as elongated blobs of a particular orientation or color (Ware, 2013). Figure 3 illustrates both the neural architecture and features processed in V1 and V2. As in many regions of the brain, neurons in V1 and V2 are retinotopically mapped, ensuring an orderly map of the visual field (Stone, 2010).

Figure 3

Diagram illustrating neural architecture and features processed in V1 and V2 (Source: Ware, 2013, Redrawn from Livingston & Hubel, 1988)



Specialized neurons in the visual cortex called “feature detectors” also contribute to visual mapping (Hubel & Wiesel, 1968; Treisman & Gelade, 1980). According to Treisman and Gelade’s Feature Integration Theory (FIT), processing of the visual field occurs in two stages (Quinlan & Humphreys, 1987). During the first stage, feature detectors, attuned to such preattentive dimensions as color, size, and orientation, code these features separately, and in parallel, resulting in separate feature maps (e.g. map of color red, map of horizontal orientation, etc) (Attneave, 1950; Handel & Imai, 1972; Garner, 1974). These maps specify not only the presence of certain features, but their locations in relation to one another (Quinlan & Humphreys, 1987). These maps are then subject to preattentive segmentation and grouping, during which features within individual maps are grouped into clusters (Quinlan & Humphreys, 1987). Then, in a second attentive stage, cross-dimensional feature clusters, such as color and shape, are combined (Quinlan & Humphreys, 1987). This act of combining feature clusters is referred to as feature integration and is essential to object recognition (Treisman & Gelade, 1980; Vecera & Gills, 1998).

All of these components of early visual processing—from pattern perception and form extraction to spatial and feature mapping—provide a neurological framework in which to understand preattentive grouping principles.

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Preattentive Grouping Principles

Gestaltists, such as Max Wertheimer, were among the first to recognize the ubiquity of perceptual groupings (Wertheimer, 1938; Palmer et al., 2003). In his influential 1923 article, Wertheimer proposed a set of grouping principles, including proximity, similarity (e.g. color, size, orientation), continuity, and closure, based on the concept of *Pragnanz*—the mind's tendency to perceive a stimulus in its simplest form (Wertheimer, 1938).

While the rationale behind these principles was flawed, subsequent research has since provided scientific support for these principles, based in preattentive processing (Palmer, 1999; Palmer et al., 2003). The research has also yielded additional preattentive grouping principles, including alignment (Beck, Rosenfeld, and Ivry, 1989), common region (Palmer, 1992; Beck and Palmer, 2002), and connectedness (Palmer & Rock, 1994), which can be rapidly perceived. These preattentive grouping principles (illustrated in Figure 1) can best be illustrated through their application in a real world case.

Use Case for IRS 1040 Tax Form

Millions of US taxpayers are required to complete and submit a 1040 federal income tax form (see Figure 2) each calendar year. The form contains sections in which users are required to fully and accurately report sensitive personal information, such as social security numbers, marital status, adjusted gross income, and alimony. Successful entry of information can yield a tax refund, while mistakes, or failure to submit, can lead to re-filings, penalties, and potentially costly and time-consuming audits. Due to the importance of this document and its widespread use by millions of US citizens of diverse ages, socioeconomic, cultural, and educational backgrounds, the usability of this document is of paramount importance. While select preattentive grouping principles are successfully employed in some respects, there is significant room for improvement.

Please note that the complexity of the form merits an in-depth evaluation, beyond the scope of this paper. The select design changes suggested below are emblematic of the types of improvements that should be made to this form on a global scale.

Evaluation of Preattentive Grouping Principles in IRS 1040 Tax Return Form

Alignment

Alignment can have a very strong influence on preattentive grouping. Beck, Rosenfeld, and Ivry (1989) demonstrated this through a series of experiments in which participants were shown groups of squares and blobs embedded in a display of randomly spaced distractors. When the target elements (i.e. the squares and blobs) were aligned along a straight edge, participants were able to more easily detect the group (Beck et al., 1989).

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Alignment is among the most powerful preattentive grouping principles at play in the IRS 1040 tax return form. Prompts and answer fields within each section are generally vertically and horizontally aligned, correctly implying connection. For instance, in the adjusted gross income section (see Figure 4A), both numbered prompts and answer fields are horizontally and vertically aligned. However, in other sections, such as filing status (see Figure 4B), this principle is not upheld. Here filing status options are split into two vertical columns, separating options 1-3 from options 4-5. As a result, options 4 and 5 form what appears to be a separate and unrelated group. The design would benefit from more consistent alignment of related prompts and answer fields (see Figure 4C)

Figure 4

A) Alignment of prompts and answer fields in adjusted gross income section

Adjusted Gross Income			
23	Educator expenses	23	
24	Certain business expenses of reservists, performing artists, and fee-basis government officials. Attach Form 2106 or 2106-EZ	24	
25	Health savings account deduction. Attach Form 8889	25	
26	Moving expenses. Attach Form 3903	26	
27	Deductible part of self-employment tax. Attach Schedule SE	27	
28	Self-employed SEP, SIMPLE, and qualified plans	28	
29	Self-employed health insurance deduction	29	
30	Penalty on early withdrawal of savings	30	
31a	Alimony paid b Recipient's SSN ▶	31a	
32	IRA deduction	32	
33	Student loan interest deduction	33	
34	Tuition and fees. Attach Form 8917	34	
35	Domestic production activities deduction. Attach Form 8903	35	
36	Add lines 23 through 35	36	
37	Subtract line 36 from line 22. This is your adjusted gross income ▶	37	

B) Misalignment in filing status section

Filing Status	
1 <input type="checkbox"/> Single	4 <input type="checkbox"/> Head of household (with qualifying person). (See instructions.) If the qualifying person is a child but not your dependent, enter this child's name here. ▶
2 <input type="checkbox"/> Married filing jointly (even if only one had income)	5 <input type="checkbox"/> Qualifying widow(er) with dependent child
3 <input type="checkbox"/> Married filing separately. Enter spouse's SSN above and full name here. ▶	

C) Redesigned filing status section, incorporating preattentive principle of alignment

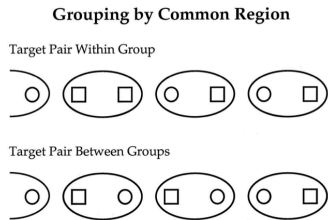
Filing Status	
1 <input type="checkbox"/> Single	
2 <input type="checkbox"/> Married filing jointly (even if only one had income)	
3 <input type="checkbox"/> Married filing separately. Enter spouse's SSN above and full name here. ▶	
4 <input type="checkbox"/> Head of household (with qualifying person). (See instructions.) If the qualifying person is a child but not your dependent, enter this child's name here. ▶	
5 <input type="checkbox"/> Qualifying widow(er) with dependent child	

Common Region

Common region is another strong determinant in preattentive grouping. When elements are placed within regions defined by a contour or shared color, they are more easily grouped (Palmer, 1992; Palmer & Rock, 1994; Beck & Palmer, 2002). Beck and Palmer (2002) demonstrated this principle by asking participants to indicate if a row of elements contained adjacent squares or circles (see Figure 5). Participants were able to more quickly identify target elements when they appeared in the same region, defined by an oval contour, as opposed to distinct, albeit adjacent, regions (Beck & Palmer, 2002)

Figure 5

Stimuli from experiment testing impact of common region on grouping (Source: Beck & Palmer, 2002)



Common region is among the most influential preattentive features at play in the 1040 form. At a glance, the sky blue shaded regions of the 1040 (see Figure 2) constitute a large common region, which unites numerous sections of the form together (e.g. header, filing status and income prompts, etc). Though highly salient, these blue shaded common regions are misapplied, since the elements it appears to group bear no logical connection to one another. This same issue is apparent in the “Sign Here” section (see Figure 6A), where a white box groups sections intended for the user, with the “Paid Preparer Use Only” sections below.

The opposite problem exists as well, whereby elements that should be grouped together are perceptually separated due to the arbitrary use of common region. This is most problematic in sections where prompts and their respective answer fields are segmented into separate regions via contour and varying common region color. For instance, though horizontally aligned, the segmentation of question 32 into three regions separates, rather than unites, these related fields (see Figure 6B). In addition, the excessive segmenting of information via contour creates arbitrary regions, which have no purpose, except to distract and confuse the user (see Figure 6C) (Tufte, 1990). The design would benefit from both a reduction in contour and the more deliberate use of color shading (see Figure 6D).

Figure 6

A) Improper grouping of unrelated fields by common region

Sign Here <small>Joint return? See instructions. Keep a copy for your records.</small>	Under penalties of perjury, I declare that I have examined this return and accompanying schedules and statements, and to the best of my knowledge and belief, they are true, correct, and complete. Declaration of preparer (other than taxpayer) is based on all information of which preparer has any knowledge.			
	Your signature	Date	Your occupation	Daytime phone number
Paid Preparer Use Only	Spouse's signature. If a joint return, both must sign.	Date	Spouse's occupation	If the IRS sent you an Identity Protection PIN, enter it here (see inst.)
	Print/Type preparer's name	Preparer's signature	Date	Check <input type="checkbox"/> if self-employed PTIN
	Firm's name ▶	Firm's EIN ▶		
	Firm's address ▶	Phone no.		

Form **1040** (2013)

B) Problematic separation of prompts from their respective answer fields by color and contour, creating separate common regions. Question 32 is divided into three common regions, one for the prompt (“32 IRA deduction”), one for the numbered answer box (“32”), and one for the entry field (blank field).

32	IRA deduction	32	
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C) Sample of excessive regional segmentation, which results in regions or groups of regions with no purpose (see extraneous columns highlighted in purple).

Adjusted Gross Income	23	Educator expenses	23					
	24	Certain business expenses of reservists, performing artists, and fee-basis government officials. Attach Form 2106 or 2106-EZ	24					
	25	Health savings account deduction. Attach Form 8889	25					
	26	Moving expenses. Attach Form 3903	26					
	27	Deductible part of self-employment tax. Attach Schedule SE	27					
	28	Self-employed SEP, SIMPLE, and qualified plans	28					
	29	Self-employed health insurance deduction	29					
	30	Penalty on early withdrawal of savings	30					
	31a	Alimony paid b Recipient's SSN ▶	31a					
	32	IRA deduction	32					
	33	Student loan interest deduction	33					
	34	Tuition and fees. Attach Form 8917	34					
	35	Domestic production activities deduction. Attach Form 8903	35					
	36	Add lines 23 through 35	36					
37	Subtract line 36 from line 22. This is your adjusted gross income ▶	37						

D) Redesigned IRA deduction field. See 4B for original.

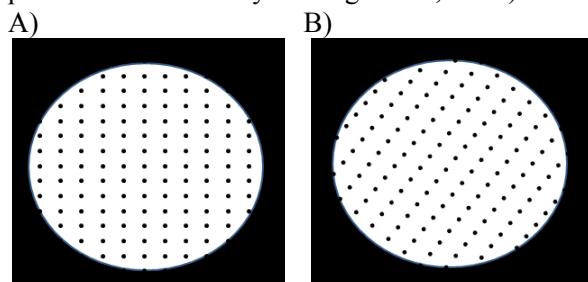
32 IRA deduction	<input type="text"/>
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Proximity

Another significant factor in preattentive grouping is proximity. Kubovy and Wagemans (1995) demonstrated this through a series of experiments using displays of geometric dots arranged at varying proximities, such as those seen Figure 7. Participants were shown these patterns for 100 msec, after which they were asked to report the direction in which the dots appeared to form “strips” (Kubovy & Wagemans, 1995). Dots in close proximity were not only shown to be grouped together, but the likelihood of this grouping was directly tied to proximity. As the distance between the dots increased, the probability that they would be grouped decreased exponentially (Kubovy & Wagemans, 1995). In addition, numerous studies have shown that utilizing negative space between perceptual groupings can aid target identification by reducing or eliminating interference from surrounding distractors (Baylis & Driver, 1992).

Figure 7

Displays of dots arranged by proximity at vertical and diagonal orientations (Based on dot patterns from Kubovy & Wagemans, 1995).



Numerous proximity issues are apparent within the 1040 form. For instance, in the income section (see Figure 8A), the prompt for “alimony received” is so spatially distant from the answer field, the user would be unlikely to preattentively group the two fields. This is exacerbated by the improper use of common region, discussed earlier, which further segments the “alimony received” prompt from the answer field. The prompts for 15b and 16b are also positioned more

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closely to the 15a and 16a entry fields than their own fields, resulting in incorrect preattentive grouping by proximity (see Figure 8A). Similarly, the “Phone no.” prompt (see Figure 8B) is ambiguously positioned between two entry fields, such that the user would be unlikely to accurately group the prompt with the correct answer field (to the right) at a glance (Baylis & Driver, 1992). Instead, the user would need to engage higher level processing to analyze the stimuli and contextual surroundings, perhaps noticing and heeding the black arrow pointing to the right-side entry field. Regardless, in both instances shown in 8A and 8B, the lack of clear preattentive grouping could lead to errors. The design could be improved by better aligning related elements, increasing their proximity, and making better use of negative space (see Figure 8C).

Figure 8

A) Proximity issues in income section marked in red

Income		7	Wages, salaries, tips, etc. Attach Form(s) W-2	7	
	8a	Taxable interest. Attach Schedule B if required	8a		
	b	Tax-exempt interest. Do not include on line 8a	8b		
	9a	Ordinary dividends. Attach Schedule B if required	9a		
	b	Qualified dividends	9b		
	10	Taxable refunds, credits, or offsets of state and local income taxes	10		
	11	Alimony received	11		
	12	Business income or (loss). Attach Schedule C or C-EZ	12		
	13	Capital gain or (loss). Attach Schedule D if required. If not required, check here <input type="checkbox"/>	13		
	14	Other gains or (losses). Attach Form 4797	14		
Attach Form(s) W-2 here. Also attach Forms W-2G and 1099-R if tax was withheld.	15a	IRA distributions	15a		b Taxable amount
	16a	Pensions and annuities	16a		b Taxable amount
If you did not get a W-2, see instructions.	17	Rental real estate, royalties, partnerships, S corporations, trusts, etc. Attach Schedule E	17		

B) Proximity issues in third party designee section

Third Party Designee	
Do you want to allow another person to discuss this return with the IRS (see instructions)? <input type="checkbox"/> Yes. Complete below. <input type="checkbox"/> No	
Designee's name ▶	Phone no. ▶
	Personal identification number (PIN) ▶

C) Redesigned third party designee section

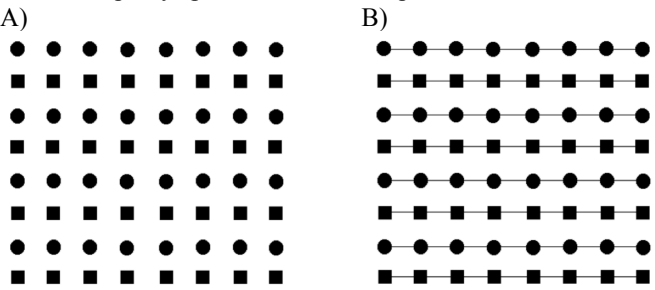
Third Party Designee	
Do you want to allow another person to discuss this return with the IRS (see instructions)? <input type="checkbox"/> Yes. Complete below. <input type="checkbox"/> No	
Designee's name ▶	
Phone no. ▶	
Personal identification number (PIN)	

Connectedness

Connectedness can also enable preattentive grouping when used well. Han, Humphreys, and Chen (1999) demonstrated this principle by presenting participants with alternating rows of equally spaced circles and squares (see Figure 9A & 9B). When the rows were connected by lines, both participant reaction times and error rates in identifying target rows were reduced (Han et al., 1999).

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Figure 9
Rows of equally spaced circles and squares, with and without connecting lines. (Source: Han et al., 1999)



While the IRS 1040 form incorporates some elements of connectedness, such as the dotted lines that connect prompts to entry fields (see Figure 10A), these are insufficient to cue the preattentive grouping of these elements. Due to the wide spacing and lack of proximity between the dots, they are more likely to be preattentively grouped as separate elements, than a continuous line (Kubovy & Wagemans, 1995). The addition of a solid and thin low contrast contour connecting prompts and answer fields, as well as the subtle use of saturation level to distinguish shaded common regions, would facilitate more rapid and accurate grouping of these elements (see Figure 10B).

Figure 10
A) Sample of connecting line usage

11	Alimony received	11		
12	Business income or (loss). Attach Schedule C or C-EZ	12		

B) Redesigned version of 6A form, utilizing a solid and thin low contrast contour and alternating blue rows at two slightly different saturation levels.

11	Alimony received	<input type="text"/>
12	Business income or (loss). Attach Schedule C or C-EZ.	<input type="text"/>

Conclusion

Preattentive grouping principles are deeply rooted in the neurology of the brain. They enable humans to quickly and efficiently find structure amidst visual chaos. When thoughtfully applied to design, the principles of common region, alignment, proximity, and connectedness can provide users with a sense of order and peace of mind (Whitson & Galinsky, 2008).

At a glance, the design of IRS 1040 is imposing at best, overwhelming and anxiety-provoking at worst. While alignment, common region, proximity, and connectedness are successfully used in some instances, these preattentive grouping principles could be much better deployed. As is, the current design promotes frustration, mistakes, and even abandonment, which not only negatively impact the user, but also the IRS, which must devote additional time and resources to audits and investigations. Additionally, the poor user experience associated with the 1040 can extend beyond the form itself, souring opinions about the larger governmental organization.

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By applying the preattentive design changes suggested above, such as making better use of common region and better connecting prompt and answer fields through connectedness, the 1040 could be greatly improved. This preattentively pleasing design would likely lead to not only a better user experience, but a reduction in the number of re-filings and audits, saving both government and tax payer time and money.

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